Green Synergy Solutions to Net-Zero Emissions Based on Bioenergy Technologies for Resilience and Sustainability

APEC Policy Partnership on Science, Technology and Innovation

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FOREWORD

APEC-ACABT presents this report on the project *Green Synergy Solutions to Net-Zero Emissions Based on Bioenergy Technologies for Resilience and Sustainability* supported by APEC Sub-Fund on Micro-, Small and Medium Enterprises (MSMEs) managed by APEC SMEWG with co-sponsorships of the APEC PPSTI delegations from Chile; Indonesia; Malaysia; the Philippines; and Thailand for the proposing member economy – Chinese Taipei.

This report provides information on the project implementation – outputs and the derivative impact – outcomes for the APEC project. The outputs included the Policy Brief from the literature review and the Green Synergy Solutions Event – APEC Workshop, APEC Training Course, and Demo-Site Best Practice, featuring two scopes – technical and social solutions. The outcomes resulted from the outputs as the recommendations based on the key issues in the Policy Brief and formed at the Green Synergy Solutions Event. The recommendations from the APEC Workshop are key findings on energy transition and societal transformation for Net-Zero Emissions, and those from the APEC Training Course are key learnings on STI entrepreneurship and SME ESG practice. Through the above outputs and outcomes, this project sets a collaborative and connective platform for capacity building on relevant stakeholders from government, academia, research institutes, and public and private sectors.

APEC-ACABT has successfully collaborates with other APEC specialized centers – APEC-CTF, APERC and APEC-SCMC – under the framework of APEC PPSTI, APEC EWG, and APEC SMEWG's Strategic Plans to promote Green Synergy Solutions for Emissions, contributing to interconnection for societal resilience, to innovation for environmental sustainability, and to inclusion for economic equality for a net-zero future in the APEC region.

ACKNOWLEDGEMENTS

This APEC project, *Green Synergy Solutions to Net-Zero Emissions Based on Bioenergy Technologies for Resilience and Sustainability*, was executed by APEC-ACABT, supervised by PPSTI, and funded by the APEC Sub-Fund on Micro, Small and Medium Enterprises (MSMEs). Established in 2016 and voluntarily contributed by Canada and Chinese Taipei, this Sub-Fund aims to involve developing MSMEs in project activities to support the building of inclusive economies in the APEC region.

Besides, as the project is co-funded by NSTC, which sponsors APEC-ACABT. The *New South Bound Science and Technology Cooperation (NSSTC)* also benefits from this report for its collective and comprehensive strategic work to expand and deepen international collaboration on scientific research and technological development between Chinese Taipei and non-/APEC member economies in South Asia, Southeast Asia, and Oceania.

In addition, the project had the co-sponsorship of APEC member economies' PPSTI delegations from MinCiencia, Chile; BRIN, Indonesia; MOSTI, Malaysia; DST, the Philippines; and MHESI, Thailand for the proposing economy – Chinese Taipei. The project activities have supports from the participation of representatives from other APEC member economies' delegations, such as CONCYTEC, Peru; DA, the Philippines; NSTDA, MHESI, Thailand; NXPO, MHESI, Thailand; and MOST, Viet Nam.

APEC cross-fora and centers collaboration has played an essential role in the success of this project. The fora involved in the project activities include PPSTI, SMEWG, and EWG-EGNRET. Furthermore, APEC specialized centers such as APERC, Japan; APEC-SCMC, Chinese Taipei; and APEC-CTF, Thailand, engaged in the Green Synergy Solutions Event actively with their representative experts' event attendance for giving speeches and/or holding panel discussions.

Moreover, experts from ENTEC/NSTDA, Thailand, and adiCET, CMRU, Thailand, as the leading researchers of this project, conducted the literature studies of Policy Review. Finally, the Green Synergy Solutions Event, including the APEC Workshop, APEC Training Course, and Demo-Site Best Practice, was implemented by teams from FCU, Chinese Taipei; CMRU, Thailand; and MJU, Thailand (APEC-ACABT Chiang Mai Branch).

TABLE OF CONTENTS

ACRONYMS

APEC-ACABT	APEC Research Center for Advanced Biohydrogen Technology
APEC-CTF	APEC Center for Technology Foresight
APERC	Asia Pacific Energy Research Centre
APEC-SCMC	APEC SME Crisis Management Center
ASEAN	Association of Southeast Asian Nations
BRIN	National Research and Innovation Agency
CMRU	Chiang Mai Rajabhat University
CQU	Chongqing University
EWG-EGNRET	Energy Working Group - Expert Group on New and Renewable Energy Technologies
FCU	Feng Chia University
HCMUT	Ho Chi Minh City University of Technology
HUST	Ha Noi University of Science and Technology
ILO	International Labour Organization
ITRI	Industrial Technology Research Institute
KKU	Khon Kaen University
MJU	Maejo University
NSTDA	National Science and Technology Development Agency
NXPO	Office of National Higher Education Science Research and Innovation Policy Council
OECD	Organisation for Economic Cooperation and Development
PhilRice	Philippine Rice Research Institute
PPSTI	Policy Partnership on Science, Technology and Innovation
SMEWG	Small and Medium Enterprises Working Group
UCR	University of California - Riverside
UDEC	University of Concepción
UKM	National University of Malaysia
UQ	University of Queensland
UNEP	UN Environment Programme
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
UNFCCC	UN Framework Convention on Climate Change
UNIDO	UN Industrial Development Organization
VNU-HCM	Viet Nam National University - Ho Chi Minh City

GLOSSARIES

Bio-Circular-Green (BCG) Economy	BCG models integrate three economic approaches, for which technology and innovation are used to create value, reduce waste, advance resource efficiency, and promote a sustainable business model with holistic efforts to achieve more balanced, inclusive, and sustainable growth. (Source: APEC)
Corporate Social Responsibility (CSR) / University Social Responsibility (USR)	CSR is a management concept whereby companies integrate social and environmental concerns in their business operations and interactions with their stakeholders. (Source: UNIDO) USR is the obligation of higher education institutions to promote and create knowledge and social norms in support of societal values and expectations.
Environmental, Social & Governance (ESG)	ESG is a framework used to assess and measure the sustainable and ethical impacts of an organization's business practices and performance. (Source: UNEP)
Green Synergy / Green Synergy Solutions	Green Synergy is a concept of systematic integration of all green growth policies, methodologies, and technologies. Green Synergy Solutions is a green symbiotic system that integrates all green growth approaches and technologies that are complimentary, cooperative, and harmonic to factor X for productivity and resource-saving. For example, the application of integrative renewable energy with heat and hydrogen storage without a battery system to a smart grid with low costs. (Source: APEC-ACABT)
Micro-, Small, and Medium Enterprises (MSMEs)	MSMEs refer to micro enterprises with 1–10 employees, small enterprises with 10–50 employees, and medium-sized enterprises employing 50–200 employees, or even up to 250. The definitions vary among economies. Though various measures/criteria are used for defining MSMEs, such as number of employees, invested capital, assets, sales volume, and production capacity, employment is the most frequently used. (Source: UNESCAP)

INTRODUCTION

Achievement of Net-Zero Emissions requires decarbonization to reduce GHG emissions to a negligible amount that could be absorbed and stored naturally for climate change mitigation. World economies have reached a consensus to limit global temperature increase by international efforts to prevent the consequences of climate change. APEC member economies, with nearly 40 percent of the world population and over 60 percent of the global Gross Domestic Product (GDP) activities, have engaged in reaching decarbonization targets by 2030 and Net-Zero Emissions by 2050-2070 (**Table 1**). Nevertheless, challenges to the net zero transition are emerging, requiring nothing less than energy and economic transition concerning the impact of human activities on the natural surroundings in the poor economy-society-environment relationships nowadays.

Economy	2030 Reduction target (%)
Australia	• Reduce GHG emissions by 43% below 2005 levels by 2030
Brunei Darussalam	• Reduce GHG emissions by 20% relative to BAU levels by 2030
Canada	• Reduce GHG emissions by 40 – 45% below 2005 levels by 2030
China	• Peak CO_2 emissions before 2030 • Reduce CO_2 emissions per unit of GDP by over 65% from 2005 level by 2030
Chile	• Peak GHG emissions by 2025 • GHG emissions level of 95 million tonnes CO2e by 2030
Hong Kong, China	• Reduce emissions by 26 – 36% by 2030 below its 2005 levels
Indonesia	• Reduce GHG emissions by 31.89% relative to BAU levels by 2030 • Increase reduction to 43.20% by 2030, subject to international support
Japan	• Reduce GHG emissions by 46% by 2030 from its fiscal year 2013 levels • Increase efforts to further reduce by 50%
Korea	• Reduce GHG emissions by 40% by 2030 from its 2018 levels.
Malaysia	• Reduce GHG emissions intensity (against GDP) by 45% in 2030 from 2005 levels
Mexico	• Reduce GHG emissions by 30% relative to BAU levels by 2030 (Unconditional) • Reduce GHG emissions by 35% relative to BAU levels by 2030 (Conditional)
New Zealand	• Reduce GHG emissions by 50% by 2030 from 2005 levels.
Papua New Guinea	• Carbon neutrality within its energy industries sub-sector by 2030
Peru	• Reduce GHG emissions by 30% relative to BAU levels by 2030 • Further reduce up to 40%, subject to international support
The Philippines	• Reduce GHG emissions by 75% relative to BAU levels by 2030 • (2.71% unconditional, and 72.29% conditional)
Singapore	• Reduce GHG emissions to around 60 million tonnes of CO2e in 2030
Russia	• Reduce GHG emissions to 70% relative to 1990 levels by 2030
Chinese Taipei	• Reduce GHG emissions by 50% relative to BAU levels by 2030
Thailand	• Reduce GHG emissions by 30% relative to BAU levels by 2030 • Further reduce up to 40%, subject to enhanced support.
The United States	• Reduce its GHG emissions by 50 – 52% below 2005 levels by 2030
Viet Nam	• Reduce GHG emissions by 15.8% relative to BAU levels by 2030 • Further reduce up to 43.5%, subject to international support

Table 1. APEC economies adopt ambitious decarbonization targets (Source: APERC)

Green Synergy Solutions synergize green technologies in a symbiotic system to achieve Net-Zero Emissions more effectively and efficiently.

Bioenergy, produced from biomass that absorbs carbon through photosynthesis, could be a near-zero-emission fuel after the carbon is released in an equivalent amount as absorbed after biomass combustion. However, human activities, especially in developing economies, produce traditional bioenergy from biowaste through unsustainable processes for economic purposes, which significantly causes GHG emissions, polluting the natural environment and driving climate change. The ongoing climate challenge needs systematic solutions to develop green and sustainable powers to balance the economy, environment, and society [**1**]. Applicable in cases of biowaste-to-bioenergy, Green Synergy Solutions provides a way for complementary and cooperative production with resource efficiency and waste management.

BCG models, where energy is an important pillar, integrate bio-, circular, and green economic approaches, in which STI could be used for creating economic value of biowaste-to-bioenergy through green business models by MSMEs.

Derived from the APEC 2022 *Balance in all Aspects: Sustainability through renewable energy*, the *Bangkok Goals on Bio-Circular-Green (BCG) Economy* encompasses three key areas: **1.** Bioeconomy as the production of renewable biological resources and their conversion into value added products; **2.** Circular economy as the reuse and recycling of resources; and **3.** Green economy, involving 1. and 2., as keeping economy, society and the environment in harmonic relationships [**2**]. BCG models, which utilize integrative economic approaches, can facilitate the transition to sustainable energy and economic systems. MSMEs play a crucial role in driving the BCG economy by developing innovative and entrepreneurial solutions based on science and technology to address the challenges associated with the energy and economic transition towards Net-Zero Emissions [**3**].

Net-zero transition creates a secure and thriving future for resilient growth of society and sustainable development of environment within BCG economy.

By taking a holistic approach to the challenges of transitioning to Net-Zero, using BCG models that consider the relationships between the economy, society, and the environment, human society can thrive despite change, and the natural environment can continue to function effectively without a decline in quality. Society would become resilient, developing into a robust and adaptive system capable of adjusting, recovering, and flourishing amidst the disruptions caused by climate change. Meanwhile, the environment would remain sustainable, functioning as a balanced and efficient system that ensures the long-term health of ecosystems through waste reduction and resource conservation. Through Green Synergy Solutions with BCG models, the energy and economic transition can enhance societal resilience and promote environmental sustainability, paving the way for a Net-Zero future [**4, 5**].

OBJECTIVES

The project aims to **1.** support PPSTI's goal of capacity building in innovative growth with knowledge and experience sharing among private and public stakeholders; **2.** correspond with EWG's mission to reduce the carbon intensity of energy supply and usage in developing economies, and EGNRET's objective to promote the development of new and renewable energy technologies; and **3.** align to SMEWG's emphasis on the priority of innovation and entrepreneurship by creating opportunities for green business model development for young entrepreneurial trainees. Based on the above, the objectives are as follows.

To build capacity for APEC member economies on Green Synergy Solutions to energy and economic transition for Net-Zero Emissions.
To facilitate the Net-Zero transition, Green Synergy Solutions could be a systematical way to integrate green technologies for complementary and cooperative production with resource efficiency and waste management [**6, 7**]. To promote the above concept, APEC-ACABT sets an internationally collaborative and connective platform among academia, research institutes, and public and private sectors for APEC member economies. This platform contributes to achieving Net-Zero Emissions based on advanced, affordable, innovative, and practical green energy technologies with BCG economic models to deal with the impact of climate change through societal resilience and environmental sustainability.

To encourage green innovation and entrepreneurship, to enable young entrepreneurs, and to ensure their business competitiveness for building foundation of BCG economy.
MSMEs, which account for over 97 percent of the business sector in the APEC region, are vital sources of innovative and entrepreneurial solutions and play a key role in driving economic growth in the context of the BCG economy. The current trend towards a Net-Zero transition is fostering green market growth, creating new opportunities for young entrepreneurs involved in environmentally friendly businesses focused on CSR/USR. Additionally, through sustainable business models, STI can be utilized by MSMEs to generate economic value from biowaste-to-bioenergy solutions. Recognizing the significant contribution of MSMEs to energy and economic transitions, this project aims to enhance the capabilities of young entrepreneurial trainees, enabling them to develop STI-driven businesses by implementing Green Synergy Solutions [**3**].

To amplify Net-Zero transition by Green Synergy Solutions for better economy-society-environment relationships in resilient communities with sustainable development.
Green Synergy Solutions for Net-Zero transition synergize societal resilience and environmental sustainability by fostering healthier ecosystems, stabilizing energy systems, and supporting BCG economies. On one hand, a resilient community supports a sustainable environment as it is equipped with green energy and is enabled to protect the ecosystem. On the other, sustainable development builds a resilient society as functioning ecosystem services reduce communities' vulnerability to climate change with natural resources. The effect on energy and economic transition will be amplified through Green Synergy Solutions to improve economy-society-environment relationships for a Net-Zero future [**8, 9**].

EXECUTIVE SUMMARY

APEC-ACABT's long-term mechanism utilizes and converts biomass resources, such as biowaste, into bioenergy (Technical Solutions), driving bioeconomy via business models (Social Solutions). Such mechanism designs the project framework on two scopes – **1.** Technical Solutions: Green Energy Technologies Empower Net-Zero Energy Transition and **2.** Social Solutions: BCG Economy Models Enhance Net-Zero Societal Transformation. Based on the above scopes, the project developed and delivered outputs including Policy Brief and Green Synergy Solutions Event – APEC Workshop, APEC Training Course, and Demo-Site Best Practice.

Regarding the outcomes supported by the above outputs, the APEC Workshop made the participants, especially those from developing APEC economies, obtain, maintain, reinforce, and cultivate capabilities to advance their Net-Zero policies and regulations, led to key findings for policy recommendations on green energy technologies and bio-circular-green economic models. During the APEC Training Course, participants, especially the young entrepreneurs, acquired practical viewpoints, knowledge, and experience for innovative and entrepreneurial solutions to social and environmental issues, leading to key learnings for STI entrepreneurship and SME's ESG practice.

Through the above outputs and outcomes, this project sets a collaborative and connective platform for capacity building on relevant stakeholders from government, academia, research institutes, and public and private sectors. There were 84 attendees, including 16 experts (Speakers / Panelists / Leading Researchers) and 68 participants (Delegates / Trainees) present at the Green Synergy Solutions Event. They were from 14 APEC member economies such as Australia; Brunei Darussalam; Chile; China; Indonesia; Japan; Korea; Malaysia; Peru; the Philippines; Chinese Taipei; Thailand; the United States; and Viet Nam. Two-thirds of all APEC member economies are involved in the project.

Among the attendees of the Green Synergy Solutions Event, there were 41 females (49%), including 7 experts (44%) and 34 participants (50%). The event features inclusive participation in Net-Zero energy and economic transition by underserved young entrepreneurs with MSME potential, including women, youth, and groups with untapped economic potential. Besides, as the project outputs have involved women attendees with more than 40% female participation, the results demonstrate APEC-ACABT's dedication to vigorously championing gender equality, ensuring females have the same opportunity as males to attend STEM-related activities. The outcomes have built women's capability by increasing their knowledge and experience, somehow preparing women for their careers as STI contributors, professionals, and leaders.

OUTPUTS

Based on the framework of the two scopes, the project features the outputs to achieve the objectives, including 1. Policy Review: the pre-event literature studies that indicate critical issues in the APEC economies that lead to the discussions of policy recommendations on Green Energy Transition in the APEC region and BCG Societal Transformation around Thailand; and 2. Green Synergy Solutions Event: the APEC Workshop, APEC Training Course, and Demo-Site Best Practice (Self-fund) with event sessions of experts' speeches, young entrepreneurs' pitches, panel discussions, and off-site best practices.

I. Policy Review

Policy Review is set to be written legal analysis by desktop research with secondary information on two scopes – Technical Solutions: Green Energy Technologies Empower Net-Zero Energy Transition and Social Solutions: BCG Economy Models Enhance Net-Zero Societal Transformation. It will indicate critical issues in the APEC economies that lead to the key findings that help us make valid policy recommendations as references for the panel discussion. As the authorities are engaged in the international treaty and comply with its obligation by net-zero, APEC member economies need legal studies that focus on Net-Zero policies regarding the role of energy and economic transitions.

The former scope will highlight the key issues on green energy technological development in the overall APEC region as it accounts for about 45% of global GHG emissions from fossil fuels due to its significant population. Thus, the APEC region is essential in the global efforts to achieve green energy transition for Net-Zero Emissions. The latter scope focuses on BCG economic growth around Thailand that proposed the initiative in APEC 2022 and thus makes the APEC member economy worth case-studying to figure out proper ways to design Net-Zero plans with valid policy implications for other APEC member economies referring to the adoption and application of BCG models for societal transformation.

A. Key Issues: *Green Energy Technologies Empower Net-Zero Energy Transition*

Background

At the UNFCCC Conference of the Parties (COP 21) in 2015, the Paris Agreement was adopted with the aim to respond to climate change. Based on Paris Agreement, economies started submitting Nationally Determined Contributions (NDCs) to reduce GHG emissions since 2020 [**10**]. Then reaching carbon neutrality / net-zero GHG emissions by or around mid-century was committed at COP 26 in 2021 [**11**]. COP 27 strengthen [**12**] highlighted adaptation and finance mobilization to enhance adaptive capacity, resilience, and reduce vulnerability to climate change. COP 28 came up with the historic agreement on the Global Stock Take (GST), which highlighted different possible pathways to achieve climate goals, considering national circumstances. COP 29 underlined the importance of finance for climate action with the agreed upon New Collective Quantified Goal for climate finance.

Many APEC economies pledged to mitigate climate change, resulting in commitments at different stages depending on their capacity to reduce GHG emission. Several economies committed to achieving carbon neutrality or net zero GHG emissions by 2050. Energy use in building, transportation, industry, and power sectors aim to be decarbonized by green energy technologies. Our past study [**13**] reviewed the methodology and framework of carbon neutral plans of APEC and non-APEC member economies in power, transport, and building sectors, synthesized best practices and lessons learned, and built capacity on carbon neutral policy formulation. The findings can be used to identify key green energy technologies and the mechanisms to facilitate their utilization and diffusion.

The definition of green energy may not be straightforward and may vary from economy to economy. Green energy is typically derived from natural resources that have lower environmental impact and are sustainable over the long term, e.g., wind, hydro, solar, biomass, and others renewable sources. Some parts of the world redefined the green energy to include nuclear power or even natural gas [**14**]. Revisiting the definition of green energy might be another crucial step to clearly define the scope of green energy technologies to have a solid approach towards net zero emissions in energy sector.

Policy Analysis: Green Energy Policy Strategy for Net-Zero Emissions

Tables 2-5 provide the overviews of green energy policy strategies in power generation, industry, transport, and business sectors. They were derived by a comprehensive review of the literature covering certain APEC member economies and insights from focus group discussions with public and private sectors in Thailand. They were separated into four main categories, including regulatory measures, taxation measures, supportive measures, and voluntary agreement.

Regarding the power sector, as shown in **Table 2**, the highlighted regulatory measure in the focus group meeting was the installation of energy storage systems at substations. Concurrently, financial support for the installation of renewable energy systems, as well as education and public awareness in the category of supportive, subsidy, and incentive measures, and voluntary agreement, were also raised. In addition, the projects development for GHG management, and investment in eco-friendly businesses were emphasized under the voluntary agreement, as they were derived from both the focus group discussions and comparative studies of domestic and international practices.

The key elements of the industry sector, as shown in **Table 3**, focused on regulatory measures, and supportive measures (including subsidy, and incentive), and voluntary agreement. In the regulatory measures, a one-stop service for licensing was derived from the focus group discussions. Financial support for low-carbon investments was emphasized in supportive, subsidy, and incentive measures. Besides, support for carbon credit trading as well as assessment of organizational and product carbon footprints and education and public outreach were highlighted in voluntary agreement.

In the transport sector, the implementation of carbon tax was raised under taxation measures during the focus group discussions, as shown in **Table 4**. Also, support for the transition of public transport to electric vehicles, and promotion of carbon credit sales/ carbon credit market were highlighted in the supportive (including subsidy, and incentive

measures), and voluntary agreement. Additionally, in the category of the voluntary agreement, the transition to commercial and electric vehicles, and the offsetting of remaining GHG emissions through carbon credits were also emphasized, informed by both the focus group discussions and comparative studies.

In the building sector, as shown in **Table 5**, awards for the exemplary practices/ support for pilot hotels were raised under the supportive, subsidy, and incentive measures. In the voluntary agreement, key elements included government-led education and public awareness campaigns, as well as support for carbon credits. These measures were derived from the focus group discussions. Furthermore, measures to reduce plastic waste, and promote the installation of rooftop solar panels were highlighted under the voluntary agreement, which are addressed by both the focus group discussions and comparative studies of domestic and international practices.

As for regulatory measures across the four sectors, the predominant focus is promoting the transition of energy towards green energy. Key measures include installation of energy storage system, increasing capacity of rooftop solar panels, promoting wind energy, and encouraging use of green electricity, supporting battery recycling, enhancing efficiency in the industry sector, and implementation of carbon tax. Taxation measures are also crucial for reducing energy consumption and promoting green energy technology adoption. Key taxation measures include tax incentives for investment in renewable energy project, tax exemptions, import duty exemptions for equipment and land rental fee, funding support for cell-level battery production, and reduction of import duties on electric vehicles (EV).

In summary, the predominant focus of regulatory measures across the four sectors is promoting the green energy transition. Key measures include installation of energy storage system, increasing capacity of rooftop solar panels, promoting wind energy, and encouraging use of green electricity, supporting battery recycling, enhancing efficiency in the industry sector, and implementation of carbon tax. Key taxation measures include tax incentives for investment in renewable energy projects, tax exemptions, import duty exemptions for equipment and land rental fee, funding support for cell-level battery production, and reduction of import duties on electric vehicles (EV). As new projects or ideas on decarbonization are often not bankable, financial support is needed in all sectors, particularly for low-carbon investment, EV infrastructure, and public transport promotion.

In addition, awards for exemplary practices and support for pilot projects are also emphasized as effective measures to encourage adoption of green energy technologies. Finally, voluntary measures are optional but can be highly effective for promoting green energy technologies and reducing GHG emissions. These measures include promotion of EV, assessment of carbon footprint organization and product, and solar rooftop installation. Additionally, collaboration between government agencies and local businesses is another measure that facilitates emission reduction, particularly for SMEs.

Regulatory measures	Taxation Measures	Supportive, Subsidy, and Incentive Measures	Voluntary Agreement	
Green Electricity Certification	Tax Incentives for Investment in Renewable Energy Projects	Financial Support for the Installation of Renewable Energy Systems	Developing Projects for Greenhouse Gas Management	Invest in Environmentally Friendly Businesses
Liberalized Electricity Market/Third-Party Access (TPA) to the Grid		Financial Support for Promoting Renewable Natural Gas	Education and Public Awareness	Install Solar Photovoltaic Systems
Installation of Energy Storage Systems at Substations			Carbon Capture and Storage (CCS) and Carbon Capture, Utilization, and Storage (CCUS)	RE100
Improvement of the Permitting Process for Rooftop Solar Panel Installation			Implement Proactive Measures to Reduce Emissions and Decrease Reliance on Carbon Offsets	Develop a Plan to Increase the Share of Clean Energy Electricity in the Future
Increasing the Installation Capacity of Rooftop Solar Panels Beyond 10 Kilowatts				Transition from Fossil Fuel-Based Electricity Generation to Renewable Energy Sources
Support for Domestic Battery Recycling				Green Hydrogen Pilot Projects
Support Plan for Increasing the Share of Renewable Energy from Offshore Wind Power Plants				
Utilization of Onshore and Offshore Wind Turbines				

Green: Measures Derived from Focus Group Discussions and Comparative Studies of Domestic and International Practices
Yellow: Measures Derived from Focus Group Meetings
Grey: Measures Derived from Domestic and International Policy Studies

Table 2. Overview of Policy Strategy in Power Sector [15].

Regulatory measures	Taxation Measures	Supportive, Subsidy, and Incentive Measures	Voluntary Agreement		
One-Stop Service for Licensing	Support for Waste-to-Electricity Projects through Tax Exemptions, Import Duty Exemptions for Equipment, and Exemption from Land Rental Fee	Financial Support for Low-Carbon Investments	Promotion of Electric Vehicles and Charging Stations	Assessment of Organizational and Product Carbon Footprints	Education and Public Outreach
Green Electricity Certification		Support for Small Enterprises Seeking to Achieve Carbon Neutrality	Support for Carbon Credit Trading	RE100	Reduction of Scope 3 Greenhouse Gas Emissions
Liberalized Electricity Market/Third-Party Access (TPA) to the Grid			Promotion of Alternative Energy-Powered Vessels	Reduction of Carbon Dioxide Emissions through the Utilization of Slag	Improvement of Transportation Efficiency (Scope 1)
Enhance Efficiency and Reduce Energy Consumption in Industry			Increasing the Share of Biomass Fuels and Clean Energy Sources	Utilization of Renewable Energy for Electricity and Heat Production	Greenhouse Gas Reduction Processes in Scope 1 and 2
Halting the Production and Import of Products Containing Microplastics			Zero Carbon Dioxide Emissions in New Vehicle Models	Reduction of Waste Throughout the Food Supply Chain	Application of Economic Tools to Promote Greenhouse Gas Emission Reductions
				Promotion of Public Transportation Usage	

Green: Measures Derived from Focus Group Discussions and Comparative Studies of Domestic and International Practices
Yellow: Measures Derived from Focus Group Meetings
Grey: Measures Derived from Domestic and International Policy Studies

Table 3. Overview Policy in Industry Sector [15].

Regulatory measures	Taxation Measures	Supportive, Subsidy, and Incentive Measures	Voluntary Agreement		
Enhancing Enforcement in Regulating Illegal Public Transportation	Funding Support for Cell-Level Battery Production	Support for the Transition of Public Transport to Electric Vehicles	Transition to Commercial and Electric Vehicles	Offsetting remaining greenhouse gas emissions through carbon credits	Promotion of Carbon Credit Sales/Carbon Credit Market
Urban Planning to Promote Bicycle Use	Implementation of Carbon Tax	Public Campaign to Promote Public Transportation Use	Installation of Solar Energy Systems	Utilization of hydrogen fuel	Education and Public Awareness
Regulation of the Production and Importation of New Energy Vehicles	Reduction of Import Duties on Public Transportation Vehicles	Expansion of Charging Stations / Support for the Development of Electric Vehicle Charging Infrastructure	Reduction of Non-Essential Fuel Consumption	Carbon Capture and Storage (CCS) and Carbon Capture, Utilization, and Storage (CCUS)	Reduction in Fossil Fuel Investment Proportion
Carbon Pricing	Tax Reductions for Electric Vehicles in the Business Sector	Support for the Development of Technologies, such as Wireless Charging and Solar Glass Panels	Upgrading Building Air Conditioning Systems	Development of hybrid vehicles for small cars and battery electric vehicles	Optimization of Maritime Efficiency
Regulation of Personal Vehicle Purchases	Reduction of Value-Added Tax Rates for Long-Distance Train Travel	Support for Investment in New Energy Sources, such as Hydrogen and Ammonia	Carbon sequestration through the cultivation and maintenance of green spaces		
	Exemption of Corporate Income Tax for Electric Vehicle Manufacturing Enterprises	Allocation of Funding for Rerouting Freight Transport			

Green: Measures Derived from Focus Group Discussions and Comparative Studies of Domestic and International Practices
Yellow: Measures Derived from Focus Group Meetings
Grey: Measures Derived from Domestic and International Policy Studies

Table 4. Overview of Policy in Transportation Sector [15].

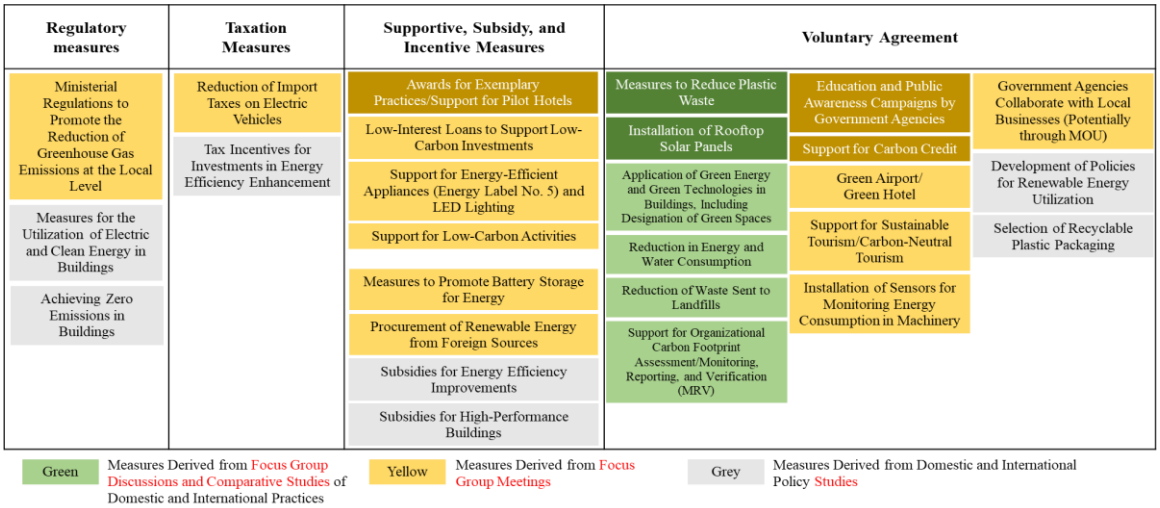

Table 5. Overview of Policy in Building Sector [15].

Supports for green energy technologies should be strategized according to stages of technological advancement. For instance, grants are appropriate for the pre-feasibility study and research and development phases. Investment subsidies are better suited for the demonstration and pilot stages. Performance subsidies align with the deployment phase towards commercial operation. Preferential debt or equity financing is appropriate for the diffusion stage, where integration at scale is needed. Finally, carbon pricing, green bonds, and climate bonds are most suitable for technologies that have reached commercial maturity and proven stability. **Table 6** illustrates the policy-technology development stage mapping.

Public Interventions at Different Stages of Technologies				Preferential Debt Financing	Carbon Pricing
Grants		Investment Subsidy	Performance Subsidy	Preferential Equity Financing	Green Bond/ Climate Bond
Pre-feasibility Study (initial idea, concept validation)	Research and Development (early to full prototype at scale)	Demonstration/ Pilot (pre-commercial demo to first of a kind commercial)	Deployment (commercial operation)	Diffusion (integration needed at scale)	Commercial Maturity (proof of stability reached)

Table 6. Policy-Technology Developmental Stage Mapping [16].

Policy Issues

The analysis shows that green energy is a critical component of the shift towards Net-Zero Emissions in energy sector with outlined below.

1. **Definition and Taxonomy for Green Energy**
   The term green energy has been used for several decades without consensus being reached regarding the definition. Many economies strictly limit green energy to only renewable energy while other economies expanded the scope to cover nuclear power and natural gas. Before identifying key clean energy technologies to empower net-zero energy transition, it is essential to take a step back and discuss the definition of green energy to ensure the correct scope of technologies to be considered.

2. **Promotion of Carbon Footprint Assessment and Carbon Credit Trading**
   Carbon credit trading is one of the interesting tools for GHG emissions reduction which benefits all sectors by providing an income stream. This should be accompanied by carbon footprint of product (CFP) promotion, which is crucial for evaluating energy consumption and wastes creation, raising environmental awareness in people to understand the impact of their activities on climate change. In particular, the assessment of carbon footprint for organization (CFO) is becoming a requirement for business, residential, and industrial sectors that cover all scopes of carbon emission.

3. **Transition from Incentives to Standards and Regulations**
   Lastly, it is critical to offer incentives to encourage the use of green energy technologies and low-carbon investment since these actions cannot be carried out successfully without incentivization. However, enormous amount of budget is required for each economy to pursue an incentive program. Given that the capacity of green energy technologies entering the market will significantly increase, government incentive program may not be a sustainable solution. It is time to consider transitioning from incentive programs to standards and regulations when the technologies become mature enough to diffuse across the economies.

With clear definition of green energy, thorough understanding of carbon footprint and emission trading, and well-planned transition from incentive programs to standards and regulations, the economies will be able to sustainably transform energy sectors to contribute toward the society with net-zero emissions.

Perspectives

The public interventions at different stages of technologies as shown in **Table 2** indicate that grants provide initial financial support for the pre-feasibility study (including the initial idea, and concept validation), and research and development for the early to full prototype at scales.

For the investment subsidy, it is the most effective for the demonstration/pilot, facilitating pre-commercial demonstrations and the first of a kind commercial. Performance subsidies support the deployment stage, including commercial operation. For technologies requiring large-scale diffusion, preferential debt financing and equity financing are important to enable broader market integration. The last stage of technologies for public intervention is the proof of commercial maturity, when stability has been achieved in the commercial phase, green bonds or climate bonds are suitable, particularly in alignment with carbon pricing strategies.

All stages of technologies show that developed economies can assist developing economies, particularly by offering low-interest loans to help them advance their targets and achieve sustainability goals. However, strong standards and regulations are crucial for ensuring these transitions are sustainable and directed for achieving carbon neutral and net zero emissions target.

B. Key Issues: *BCG Economy Models Enhance Net-Zero Societal Transformation*

Background

The Bio-Circular-Green (BCG) Economy Model is proposed as a new sustainable growth engine to drive Thailand's economic, social, and environmental development. This model integrates the bioeconomy, circular economy, and green economy principles to create a balanced approach that supports Thailand's transition towards zero carbon emissions and a sustainable future. The BCG policy was officially endorsed as part of Thailand's strategic plan under the *Twenty-Year National Strategy: 2018-2037*. This domestic strategy aims to transit Thailand into a high-income economy with resilience and sustainability.

The BCG model aligns with global sustainability goals, such as the SDGs, and addresses key challenges such as climate change, resource depletion, and environmental degradation. The Thai government has positioned the BCG model as a central element in its economic recovery and development plans, particularly in the wake of the COVID-19 pandemic. The model is considered a way to enhance the economy's competitiveness, particularly in the fields of agriculture, food, energy, and healthcare. Thailand is actively promoting BCG model at international forums, including APEC and ASEAN, to foster regional cooperation in sustainable development [**17**].

APEC endorsed the BCG Economy Model in the *Bangkok Declaration* during the APEC Economic Leaders' Meeting in November 2022. This endorsement marked a significant moment for Thailand, which championed the BCG Economy Model as a core theme during the APEC 2022. The *Bangkok Declaration* emphasized the BCG model to promote sustainable and inclusive growth across the Asia-Pacific region, addressing challenges such as climate change, environmental sustainability, and economic resilience [**17**].

Policy Analysis: BCG Policy Strategy Structure for Net-Zero Emissions in Thailand

Several APEC economies have implemented policies related to the bioeconomy, circular economy, and green economy. Below is a review of these policies and key initiatives undertaken by APEC economies in these areas.

The **bioeconomy** policies of APEC economies reflect diverse priorities based on their unique resources and economic contexts. Japan focuses on biotechnology and medical applications, investing in biopharmaceuticals and precision medicine, while Korea emphasizes a circular bioeconomy with bio-based products such as bioplastics and bioenergy. China integrates bioeconomy efforts into its *Made in China 2025* initiative, prioritizing biofuels and sustainable agriculture, whereas Australia leverages its agricultural and forestry sectors for bioenergy and waste utilization. The United States emphasizes industrial biotechnology and bio-based manufacturing through the U.S. Bioeconomy Initiative, while Canada utilizes its vast forest resources for bio-based products and renewable energy. Mexico promotes green energy and biofertilizers, focusing on agricultural residues for bioethanol production, and Indonesia capitalizes on its biodiversity to develop marine bioeconomy products like algae-based biofuels. Viet Nam integrates sustainable agriculture strategies, including organic fertilizers and biopesticides, and Chile advances bioeconomy goals through forestry and aquaculture,

emphasizing sustainable forest management and fishery waste utilization. These strategies demonstrate APEC member economies' shared commitment to leveraging biological resources for sustainability, innovation, and economic growth while addressing environmental challenges [**18, 19, 20**].

APEC economies are actively advancing **circular economy** policies to promote sustainability and resource efficiency. China leads with its *Circular Economy Promotion Law*, which mandates sustainable practices across production and consumption sectors. Malaysia has launched its *Sustainable and Circular Economy Roadmap: 2023-2040* to minimize waste and enhance natural system regeneration. Thailand integrates bioeconomy, circular economy, and green economy principles under its BCG Economy Model, focusing on resource efficiency. Korea has introduced initiatives to combat plastic waste, including hosting international negotiations for legally binding treaties on plastic pollution. Australia's *National Waste Policy Action Plan* emphasizes recycling, waste reduction, and resource recovery through industry collaboration. Chile implements *Extended Producer Responsibility (EPR)* laws, holding producers accountable for waste management and recycling. The initiatives underscore APEC member economies' shared commitment of transitioning towards a circular economy to address environmental challenges [**18, 19**].

Regarding the **green economy** policies, APEC economies are actively integrating environmental sustainability with economic development. China has implemented its *Green Growth Strategy*, focusing on renewable energy, electric vehicle infrastructure, and a domestic emissions trading system. Malaysia's *Green Technology Master Plan: 2021-2030* aims to integrate green technology across key sectors, while its *Sustainable and Circular Economy Roadmap* promotes resource efficiency and waste minimization. Thailand's BCG Economy Model combines bio-, circular, and green economic principles for sustainable growth. Australia is advancing renewable energy initiatives, aiming to become a global leader in solar, wind, and green hydrogen. New Zealand supports sustainable trade through the *Agreement on Climate Change, Trade, and Sustainability (ACCTS)*, eliminating tariffs on eco-friendly goods. Japan's *Green Growth Strategy* targets carbon neutrality by 2050 with a focus on energy, transport, and manufacturing, supported by a Green Innovation Fund. These policies demonstrate APEC member economies' commitment to address climate change and enhance resource efficiency [**18, 19**].

This policy review focuses on Thailand's BCG policy as an example of support for achieving a net-zero societal transformation. Below is an analysis of the BCG Policy Strategy Structure for Net-Zero Emissions in Thailand:

Thailand's BCG Economy Model is a transformative framework designed to drive sustainable economic growth and achieve the net-zero goal. By leveraging Thailand's biodiversity and cultural heritage, the model integrates science, technology, and innovation to create high-value goods and services, shifting from "doing more with less gain" to "doing less with greater gain." It aligns with sustainable development principles and the *Sufficiency Economy Philosophy*, promoting inclusive growth, wealth distribution to local communities, and significant reductions in resource consumption and waste. Through the integration of bioeconomy, circular economy, and green economy strategies, the model addresses critical challenges such as resource degradation, waste

management, and climate change. This holistic approach positions Thailand to transition from a middle-income to a high-income economy, while advancing toward its net-zero emissions target and ensuring a resilient and sustainable future.

1. Strategic Vision

- The BCG economy serves as a mechanism to transform Thailand into a global leader in sustainability. By leveraging Thailand's biodiversity and cultural richness, the model aims to enhance competitiveness while ensuring inclusive and sustainable growth.
- The BCG model aligns with Thailand's domestic strategies and global SDGs, integrating the Sufficiency Economy Philosophy (SEP) for resilience and sustainability.

2. Key Sectors

- The BCG model focuses on four main sectors: agriculture and food, health and wellness, energy, materials and biochemicals, and tourism and creative economy. These sectors are seen critical in achieving value-based economy and environmental footprint reduction.
- Emphasis is placed on increasing productivity, enhancing standards, and fostering innovation, particularly in high-value products and services that align with global sustainability trends.

3. Economic Impact

- The BCG economy is expected to contribute significantly to the GDP growth, aiming to increase the share of BCG-related industries from 21% to 24% of the GDP within five years.
- The BCG model promotes creating green occupations particularly in high-skilled areas, to uplift income of farmers and communities while reducing environmental degradation.

4. Net-Zero Goals

- Central to the BCG economy is the pursuit of a low-carbon society, with specific targets to reduce GHG emissions by promoting renewable energy, improving resource efficiency, and minimizing waste.
- The model supports the development of green technologies and innovations that are essential for Thailand's commitment to achieving carbon neutrality.

5. Implementation Strategy

- The BCG economic model calls for "Quadruple Helix" collaboration involving government, private sector, academia, and international networks to drive the adoption of sustainable practices.
- The strategy includes capacity building, regulatory reforms, infrastructure development, and fostering global partnerships to enhance the BCG ecosystem.

In summary, the BCG Economy Model is a comprehensive approach designed to drive Thailand's transformation towards a net-zero society, ensuring sustainable and inclusive growth while positioning the economy as a leader in green economy initiatives.

Policy Issues

To transform society toward net-zero emissions with the application of the BCG Economy Model, several key policy recommendations are required. This policy recommendation synthesizes insights from documentary review, panel discussions and presentations to provide recommendations for advancing net-zero emissions using the Bio-Circular-Green (BCG) Economy Model. The recommendations focus on key areas such as policy frameworks, technological innovation, circular economy practices, public-private partnerships, Education and Awareness, Financial Mechanisms and Incentives, Global and Regional Cooperation, and community engagement.

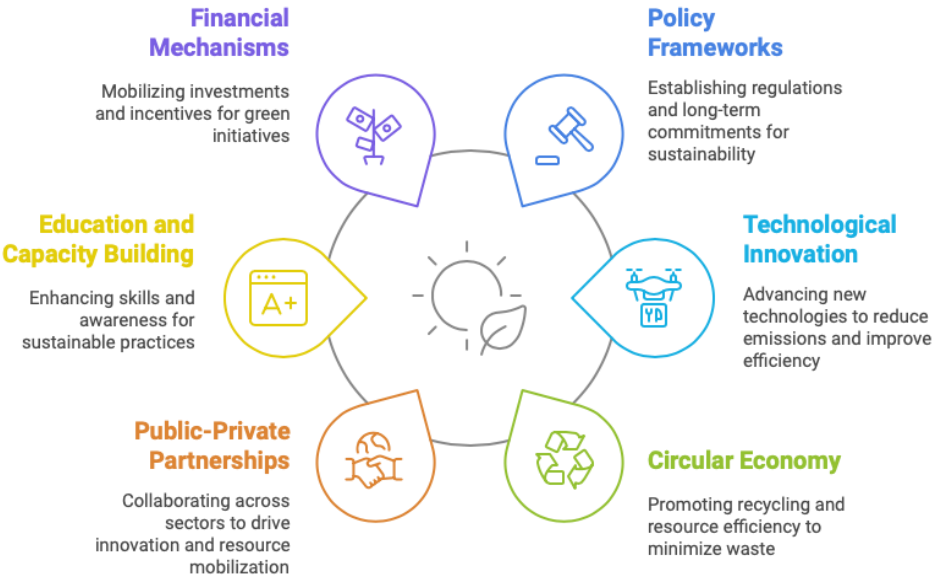

Figure 1. Policy Issues for BCG Economy Models of Net-Zero Society

1. Policy and Regulatory Frameworks

- Strong Government Commitment: Clear and supportive policies from the government are essential to drive the BCG agenda. This includes setting ambitious targets for carbon neutrality, establishing regulations that promote sustainable practices, and providing incentives for businesses and individuals to adopt green technologies.
- Environmental Regulations: Implementing stringent regulations to reduce GHG, manage waste, and protect natural resources is crucial. This also involves creating a conducive environment for the adoption of clean energy and sustainable practices.

2. Technological Innovation and Adoption

- Research and Development (R&D): Continuous investment in R&D is needed to develop new technologies that can reduce emissions and improve resource efficiency. This includes advancements in renewable energy, bio-based products, waste management technologies, and sustainable agriculture.
- Smart Technologies: Adopting smart technologies, like smart grids, energy storage systems, and resource management AI, optimizes energy use and reduces emissions.
- Biorefinery and Bioenergy: Developing infrastructure for biorefinery and bioenergy helps produce low-carbon fuels and materials and reducing reliance on fossil fuels.

3. **Circular Economy Practices**

- Resource Efficiency: Encouraging the efficient use of resources by promoting recycling, reuse, and reducing waste is fundamental. This involves rethinking product life cycles to minimize environmental impact.
- Waste Management: Implementing circular economy principles in waste management can significantly reduce emissions by ensuring that waste materials are reprocessed and reintegrated into the economy rather than being discarded.

4. **Public-Private Partnerships (PPP)**

- Collaborative Efforts: Collaboration among government, private sector, academia, and civil society is necessary to implement BCG model effectively. Public-private partnerships can drive innovation, mobilize resources, and scale sustainable practices.
- Investment in Green Infrastructure: Encouraging private sector investment in green infrastructure projects, such as renewable energy facilities, sustainable transportation, and eco-friendly industrial processes, is crucial.

5. **Education and Capacity Building**

- Public Awareness and Education: Raising awareness about the importance of sustainability and the benefits of the BCG model is essential to gain public support. Education and training programs should be implemented to equip individuals with the knowledge and skills needed to participate in a green economy.
- Workforce Development: Developing a skilled workforce capable of working in emerging green sectors is necessary for the transition. This includes retraining workers from traditional industries to adapt to new, sustainable practices.

6. **Financial Mechanisms and Incentives**

- Green Financing: Developing financial mechanism that supports green investments, such as green bonds, carbon credits, and subsidies for renewable energy, is essential. Financial incentives can help lower the cost of transitioning to sustainable practices.
- Carbon Pricing: Implementing carbon pricing mechanisms can create economic incentives for reducing emissions and investing in low-carbon technologies.

7. **Global and Regional Cooperation**

- International Collaboration: Engaging in global and regional partnerships to share knowledge, technologies, and best practices is crucial to achieve net-zero emissions. Collaboration with international organizations can enhance BCG effectiveness.
- Alignment with Global Goals: Ensuring that the BCG model aligns with global initiatives, such as the Paris Agreement and the SDGs, can strengthen international cooperation and access to global funding.

8. **Community and Cultural Engagement**

- Community Participation: Engaging local communities in the transition to a BCG economy is critical for its success. This involves supporting community-based projects that promote sustainable practices and enhance local resilience.
- Cultural Shift: Fostering a cultural shift towards valuing sustainability, conservation, and responsible consumption is essential for long-term societal transformation.

By addressing these elements, society can effectively achieve net-zero transition while fostering resilience and sustainability through the application of BCG economic model.

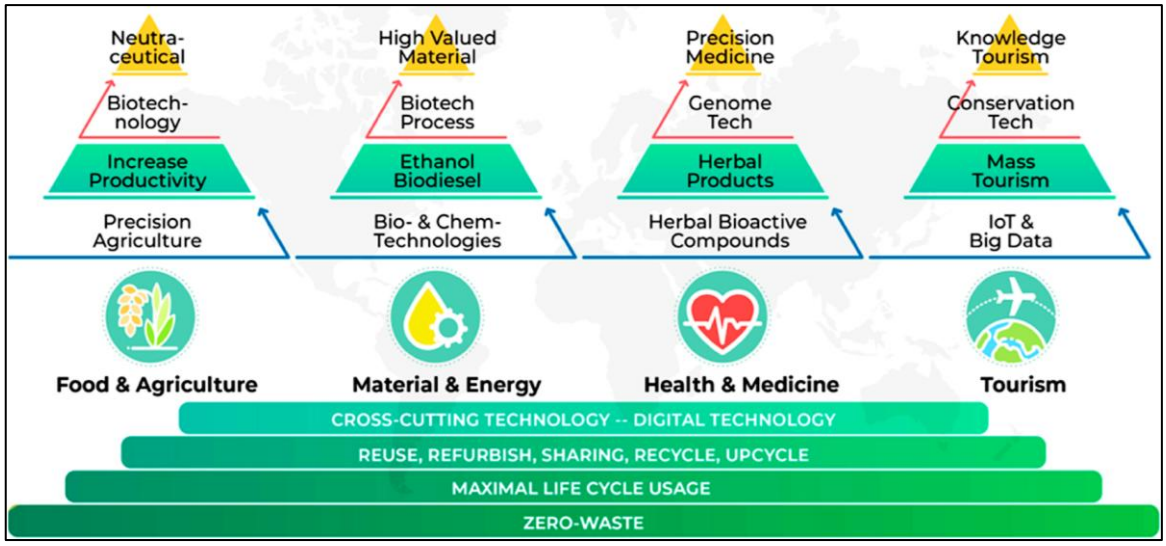

Figure 2. BCG Pillars and Value Creation.

Perspectives

The adoption of these policy recommendations will deliver significant environmental, economic, social, technological, and global impacts. Environmentally, GHG emissions will be substantially reduced, supporting Thailand's net-zero targets. Enhanced waste management and resource efficiency will mitigate environmental degradation, while the adoption of bioenergy and renewable technologies will decrease dependence on fossil fuels and combat climate change. Economically, transitioning to a green economy will drive growth and innovation, creating new market opportunities and enhancing global competitiveness. SMEs will benefit from sustainable transitions, promoting inclusive growth and reducing income disparities.

Socially, community engagement and culturally sensitive policies will ensure that local leadership is central to sustainability programs, fostering inclusivity and long-term societal transformation. Education and awareness initiatives will strengthen resilience to climate challenges and empower communities to lead change. Technologically, advancements in biorefineries and precision agriculture will revolutionize traditional sectors, creating more sustainable industries. Globally, Thailand will emerge as a leader in integrating bioeconomy, circular economy, and green economy principles, serving as a model for regional and international sustainability efforts. These collective and combined impacts will accelerate Thailand's journey toward net-zero development while ensuring resilience, inclusivity, and prosperity.

II. Green Synergy Solutions Event

Green Synergy Solutions Event involved regulators, technologists, and young entrepreneurs from public and private sectors in the APEC economies. Regulators are those responsible for regulatory issues of ESG, net-zero emissions roadmap, energy transition, and economic transformation in governmental sectors. Technologists are experts with relevant professional backgrounds in academic, industrial, and other public and private sectors. Young entrepreneurial trainees are STI talents such as undergraduates, graduates, and postgraduates working on green businesses. The above speakers and participants are the main attendants of the APEC Workshop, APEC Training Course, and Demo-site Best Practice (Self-fund).

Regulators addressed their investigations on retrospective and prospective Net-Zero development in their economies. Technologists shared their knowledge and findings on relevant theoretical and technical applications of Green Synergy Solutions. Young entrepreneurs have acquired knowledge and experience about bioenergy, net-zero, and BCG from the speeches and discussions of the APEC Workshop delivered by policymakers and experts, developed skills to find and present innovative entrepreneurial solutions in the APEC Training Course, and gained Green Synergy technical practice experience from the Demo-site Best Practice. Regulators, technologists, and other delegates exchanged ideas and opinions on relevant issues during the event.

APEC-ACABT and APEC Centers such as APEC-CTF, APERC, and APEC-SCMC facilitate cross-fora/centers dialogues and discussions on Net-Zero future with social resilience and environmental sustainability, and outlooks in the aspects of community, society, economy, and environment. The project provided an educational platform for young entrepreneurs, especially those from developing economies with women, youth, and untapped economic potentials, to address Net-Zero issues with innovative and entrepreneurial solutions. Besides, the event facilitated dialogues among government, academic institutes, research institutes, and public/private sectors to discuss suitable Green Synergy measures for economies on net-zero transition considering various economy-specific circumstances concerning geographical, environmental, economic, and social conditions.

Figure 1. Experts and Participants at the 2024 Green Synergy Solutions Event.

A. Keynotes: APEC Workshop

Technical Solutions

1. *Green Energy Transition in the APEC Region*

Nabih Matussin, APERC, Japan - Brunei Darussalam

Nowadays the electricity generation in the APEC region still relies on thermal sources that account for 63% of its total electricity generation in 2022 (**Figure 3**). The highest share – about 41% – of total renewable energy supply was from bioenergy alone while solar and wind has grown at highest rates by over 760 times and 210 times respectively since 2000 (**Figure 4**).

Although there are green energy projects in the APEC member economies, transitioning towards green energy structure presents challenges to be addressed, including expense of electricity generation from renewables, grid reliability of intermittent renewables' integration, and fund security for viability demonstration of new technologies through pilot projects, as well as regulatory hurdles and competition with established energy sources.

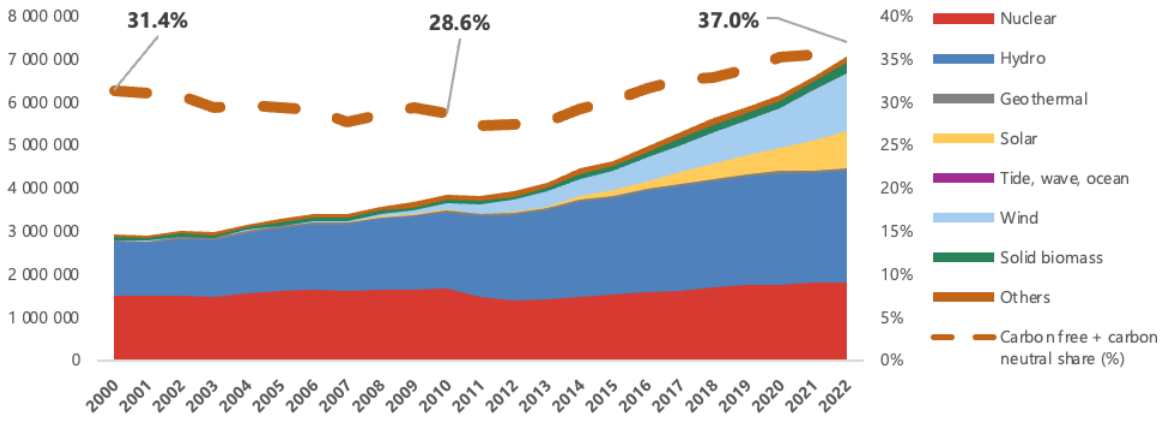

Figure 3. APEC non-carbon electricity generation by fuel, 2000 – 2022 (Terawatt-hour; TWh).

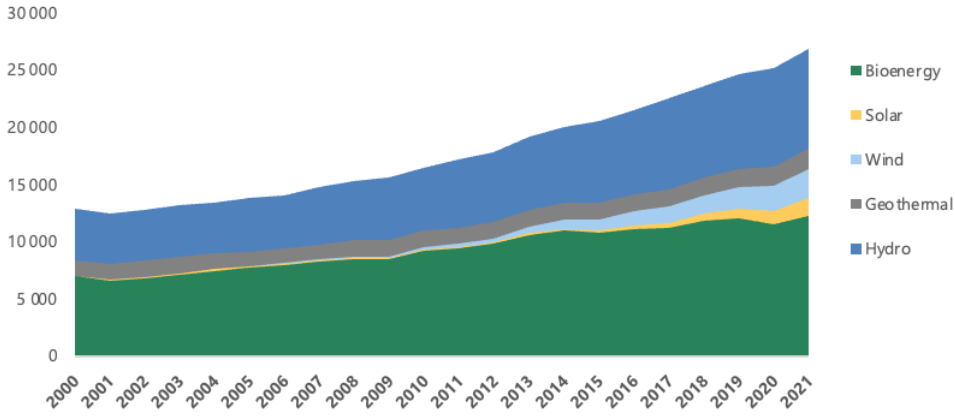

Figure 4. APEC renewables supply, 2000 – 2021 (Petajoule; PJ).

2. ***Sustainable Palm Oil-Based Green Energy Technology: Accelerating Indonesia towards Net-Zero Emissions***

SD Sumbogo Murti, Research Center for Process and Manufacturing Industry Technology, BRIN, Indonesia

Palm oil — a significant commodity for the Indonesian economy, plays a crucial role in supplying renewable hydrocarbons like biodiesel, bioavtur, and bioethanol, as well as energy derived from palm oil waste such as biogas and biomass. Sustainable utilization of palm oil has the potential to not only mitigate emissions but also enhance domestic energy security and generate additional value for the palm oil sector.

Employing palm oil-based technologies enables Indonesia to enhance its status as a frontrunner in renewable energy transition. The initiative aims to accelerate net-zero achievement through sustainable palm oil with strategic steps, including R&D on bioenergy, policies of renewables promotion, infrastructures for green energy, and cross-sector cooperation among government, corporate, and international community.

3. ***Renewable Hydrogen: An Opportunity for Chile and the Biobío Region***

Andrea Moraga, Institute of Technological Research (IIT), UDEC, Chile

Chile’s abundant renewable energy resources, such as solar and wind power, position the economy as a global leader in green hydrogen production. The *National Green Hydrogen Strategy* aims to decarbonize sectors such as transportation and heavy industry, while creating a favorable investing environment for green hydrogen for reducing carbon footprint and fostering economic growth.

UDEC plays a pivotal role as the cornerstone of collaborative network with academia, industry, government, and society for driving hydrogen initiatives in Biobío, Chile. Through the Green Hydrogen Alliance’s collaborative efforts in research, innovation, and human capital with stakeholders, the initiative positions Biobío as a strategic hub of Chile’s green hydrogen market competitiveness for decarbonization goals.

4. ***From Fossil Fuels to Renewables: Innovation Drives Japan’s Green Energy Technologies***

Helmut Yabar, Institute of Life and Environmental Sciences, University of Tsukuba, Japan – Peru

As Japan strives towards achieving net zero emissions by 2050, it spearheads a critical transition from fossil fuels to renewable energy sources. innovations and policy measures drive Japan's bioenergy technologies, focusing on biogas, biomass, and bioenergy with carbon capture and storage (BECCS).

Bioenergy sectors play integral roles in Japan's decarbonization, from municipal and agricultural waste biogas production to biomass energy for industrial and consumer heat. Adopting innovative technologies such as dry anaerobic digestion, bioenergy power plants, and local biomass recycling programs demonstrates Japan's progress in reducing emissions and creating circular economies. Bioenergy technologies are pivotal in Japan's journey toward a sustainable future for carbon neutrality by 2050.

Social Solutions

1. *Towards a Sustainable Future: Circular Economy Roadmap for APEC*

Srichattra Chaivongvilan, APEC-CTF, Thailand

APEC Circular Economy Roadmap project is focus on bioenergy technologies and green synergy solutions to achieve net-zero emissions, summarizes findings about utilizing foresight tools to identify key drivers and strategies for advancing the circular economy through 2050. Key findings include the prioritization of pollution reversal for economies with significant waste issues, and a focus on value-added circular systems for those with advanced waste management. International coordination and local innovation are identified as essentials for building effective circular systems. Critical enablers such as policy, technology, capacity building, and monitoring are highlighted as progress drivers. Needs for new business models, capacity-building programs, and technology transfer are underscored with proposed initiatives focus on converting agro-waste into functional fibers, promoting SMEs' circular business models, and implementing plastic credit programs to tackle plastic waste.

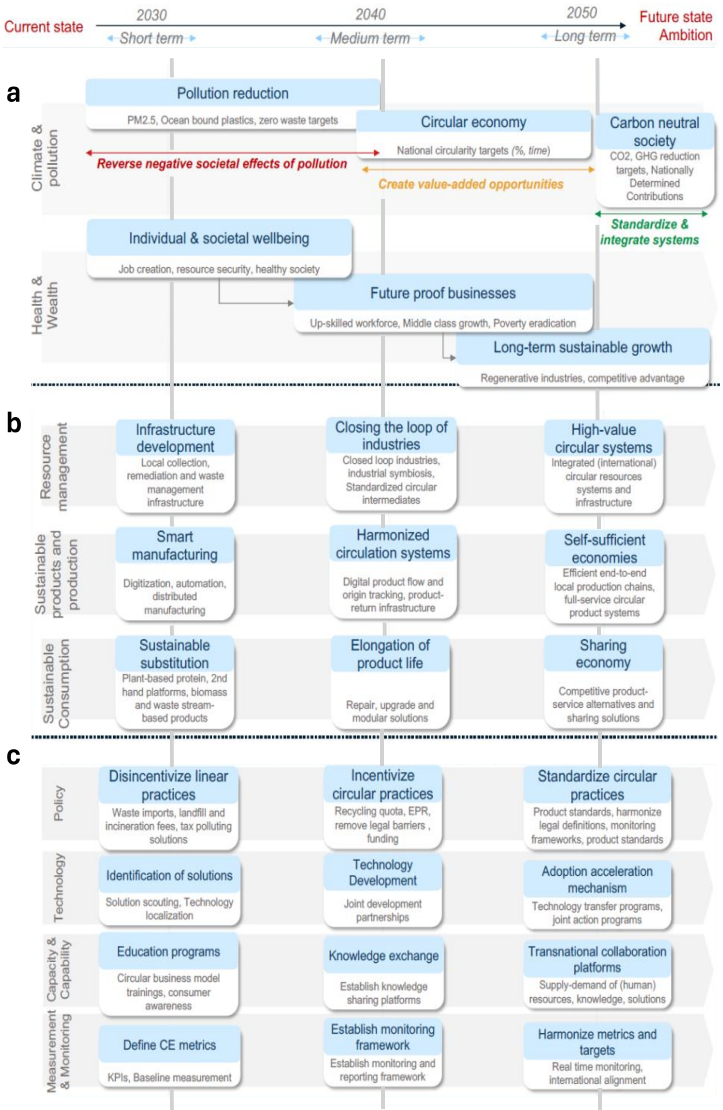

Figure 5a. Drivers
1. Economies with significant waste issues prioritize reversing pollution effects. **2.** Economies with advanced waste management focus on value-added circular systems. **3.** Standardizing best practices and integrating systems helps achieve long-term goals.

Figure 5b. Solutions
1. Resource management connects industries, creating circular systems. **2.** International coordination ensures interoperable standards across APEC. **3.** Local innovation drives sustainable consumption and product longevity.

Figure 5c. Resources/Enablers
1. Policy incentives align with adoption timelines and maturity. **2.** Technology incentives depend on industry readiness and regional availability. **3.** Capability building on education, knowledge sharing, and collaboration. **4.** Measurement begins with KPIs, progressing to harmonized reporting.

2. ***Sustainable Biomass Management in Palm Oil Milling***

Peer Mohamed, Department of Chemical and Process Engineering, UKM, Malaysia

Palm oil industry drives rural development in Malaysia and contributes nearly 40% of global vegetable oil demand. Palm oil extraction is chemical-free while only 10% of the biomass is extracted as oil, leaving substantial by-product biomass rich in cellulose, hemicellulose, and lignin, with great potential of converting into valuable bioproducts.

Lignin is an overlooked valuable source for aromatic compounds used in bio-based chemicals, resins, and bioplastics. Utilizing resources contribute to the circular economy and aligns with sustainability goals. Additionally, the palm oil industry is rapidly evolving by adopting Industry 4.0 technologies such as automation, artificial intelligence, and data analytics that enhance efficiency, optimize resource use, and reduce waste to mitigate environmental impact while remaining profitable.

3. ***Bioeconomy – Building a Global Alliance: Tackling Global Themes Head-on for Impact***

Tamara Weissflog, Global Partnerships, UQ, Queensland, Australia

Bioeconomy is a global topic and can only be realized by combining all agricultural, technical as well as social aspects of the bio-based industry and society. While academia drives technological development, impact in bioeconomy can only be achieved with industry as well as governmental framework settings. To optimize the collaborative partnership, UQ has established the Global Bioeconomy Alliance (GBA).

The ambition of GBA is to strengthen R&D cooperation, innovation transfer as well as teaching to accelerate the turnaround to a sustainable global society. To achieve its mission, GBA educates the next generation to tackle challenges of an overutilized planet and leverages international funding opportunities to develop innovative solutions to regional challenges. GBA also provides access to relevant policymakers to motivate policies to accelerate sustainable transition.

4. ***Precision Agriculture and Industrial Symbiosis: Preliminary Steps to Achieving Net-Zero Emissions in Agri- and Fisheries Sectors of the Philippines***

Hazel Biteng Alfon , PhilRice / Department of the Agriculture, the Philippines

According to the Philippine Institute of Development Studies (PIDS), the losses of domestic agricultural sectors for climate change account for 60% of the total disaster-related property damages. Additionally, the Philippines' contribution to emissions is about 0.49%, and agriculture sectors contribute about 23% to the domestic measures.

The industrial symbiosis and precision agriculture concept are tested through case studies to determine how solving environmental concerns leads to social re-engineering and economic development. Department of Agriculture is managing information of specific problems to be solved and related interventions undertaken by government agencies, civil organizations, academic institutions and business sectors.

Figure 6. Speakers present at APEC Workshop and APEC Training Course for cross-fora/centers collaboration. a. Nabih Matussin, APERC, Japan; **b.** Yau-Jr LIU, APEC-SCMC, Chinese Taipei; **c.** Srichattra Chaivongvilan (left) and Kommate Jitvanichphaibool (right), APEC-CTF, Thailand.

Figure 7. Panelists and Leading Researchers present at APEC Workshop panel discussions. a. Guang Wei JANG, ITRI, Chinese Taipei (left), Nuwong Chollacoop (middle) and Kampanart Silva (right), NSTDA, Thailand; **b.** Nguyen Hong Quan, VNU-HCM, Viet Nam (middle), Worajit Setthapun (left) and Hathaithip Sintuya (right)**,** CMRU, Thailand.

B. Keynotes: APEC Training Course

CSR / USR Solutions

1. ***Building an Innovation Ecosystem in the Inland Southern California***

Rosibel Ochoa, UC - Riverside, California, the United States

To support innovation and entrepreneurship in the Inland Southern California (InSoCal) that comprises San Bernardino, Riverside and Imperial County with more than 27,000 square miles and 5 million people, UC-Riverside has developed programs focused on providing resources to regional entrepreneurs to start and scale their companies. These companies serve as a source of quality jobs for residents. With support from federal, corporates and non-profit organizations, UC-Riverside has provided access to mentorship in technological commercialization as well as to incubator facilities, lowering barriers for local entrepreneurs to launch businesses.

UC-Riverside's commitment to the economic development in InSoCal has been reflected in **a.** the launch of the SoCal OASIS ™ regional economic development initiative focused on innovation, social inclusion and sustainability, the expertise area of the academic institute; and **b.** the pursuit of the Inclusive Accelerate Hub Designation by the California Office of the Small Business Advocate (InSoCal I HUB). The two initiatives, focus on climate resilience, adaptation and sustainability, serve as the cornerstones on UC-Riverside's strategy of regional economic growth through innovation and entrepreneurship support for small businesses.

Figure 8. UC-Riverside provides access for local entrepreneurs to incubator facilities of innovative agricultural technology for workforce development in the InSoCal.

Figure 9. UC-Riverside builds physical infrastructures, such as the SoCal OASIS ™ Park, to stimulate knowledge exchange and collaboration.

ESG Solutions

2. *Chinese Taipei's SME Just Green Transition: Policy and Cases*

Yau-Jr LIU, APEC-SCMC, Chinese Taipei

SMEs adopt ESG practices by setting clear environmental goals, engaging positively with society, and establishing strong governance. Due to limited resources, they need government support to enhance sustainability, transparency, and social responsibility. To achieve ESG goals, SMEs are recommended to adopt key steps as follows:

a. **Set goals and strategies**: Clarify ESG goals and develop corresponding strategies based on industry characteristics and market demands.
b. **Build a dedicated team**: Create a team to promote and oversee the implementation of ESG policies, ensuring that all employees understand the importance of ESG and integrate it into the corporate culture.
c. **Self-assessment:** Use questionnaires or assessment tools to evaluate current status and needs regarding ESG practices.
d. **Data report**: Collect relevant ESG data and regularly report it to external stakeholders to enhance transparency and build trust.
e. **Improvement**: Review and adjust ESG policies and provide training and workshops for employees.

Chinese Taipei's policy strategies regarding SME just transition of green transition are based on Pathway to Net-Zero Emissions in 2050, in which green transportation, vehicle electrification, and zero waste in resource recycling are included.

Figure 10. Key Steps towards ESG for SMEs.

Innovative Solutions

1. ***Micromet: A Novel Bacterial Approach to Microplastic Removal and Biogas Production***
   Team AMAL, Mahidol University, Thailand

   Environmental factors break down discarded plastic waste into smaller fragments and form microplastics. These tiny particles accumulate in water, soil, and throughout the food chain, eventually contaminating the water and food consumed by humans. The Micromet system is developed to eliminate microplastics from contaminated water by utilizing microorganisms offering an additional benefit beyond water purification. As the bacteria break down microplastics, they produce biogas, a clean and renewable energy resource. This dual-purpose technology cleans water generates biofuel that potentially power homes, businesses, and vehicles, transforming pollution into valuable resource.

2. ***From Waste to Power: A New Model for Sustainable Energy Supply in Remote Regions***
   Team EnergyEdge, FCU, Chinese Taipei

   Green energy is a key to achieving sustainability in remote rural areas where electricity shortages and energy instability are more pronounced. Facing challenges of inadequate infrastructure, the areas need the stable power supply with green energy solution. Integrating renewables, such as biomass, solar, wind, and micro-hydro, ensures a continuous and reliable power supply system.

   A key innovative solution is the conversion of household food waste into energy, reducing waste while supplying essential electricity. The system features stability and adaptability enhanced with recycled battery modules and artificial intelligence for local needs of basic electricity in diverse conditions. This integrative energy system with economic potential can reduce carbon emissions and optimize waste management for sustainable development.

3. ***Bridging Waste and Green Energy: A Continuous-flow System for Enhanced Biofuel Production and Rural Development***
   Team CQU Green Energy, CQU, China

   Bioenergy plays a pivotal role in advancing sustainable energy solutions due to its advantage as a renewable resource with lifecycle zero-carbon emissions. However, advancing process efficiency of recyclable biomass resources, such as lignocellulosic biomass and livestock manure, remains a technical challenge. Current utilization methods, such as incineration, lead to energy loss and environmental pollution.

   While the issues can be solved with a continuous-flow multistage conversion system designed for co-hydrolysis and co-fermentation of lignocellulosic biomass and livestock manure. It addresses agricultural and forestry waste management, promotes energy recovery, and contributes to net-zero energy transition by improving biofuel producing efficiency and generating economic benefits by advanced waste recycling.

4. ***Sustainable Production of Rhamnose from Palm Oil Mill Effluent (POME)***
Team RhamonoGlow, Jayabaya University, Bogor Agricultural University, Atma Jaya University, and BRIN, Indonesia

Palm oil mill effluent (POME), a waste product from palm oil processing, presents environmental challenges due to its high organic content and nutrient levels. Through microbial biosurfactant fermentation in bioreactors to produce rhamnose, a valuable cosmetic ingredient from POME, the solution aims to enhance sustainability while meeting the growing demand for this ingredient in Indonesia's cosmetic industry.

The system utilizes POME as biowaste in palm oil mill industries to reduce environmental, social, and economic impacts. It provides a cost-effective and eco-friendly alternative solution to importing rare plants traditionally used for production in Indonesia with economic opportunities for palm oil producers. For local MSMEs, such ecofriendly anti-aging cosmetic can have a great market potential.

5. ***Using Yeast Isolated from Fermented Pork Roll for Chitin Recovery from Shrimp By-products***
Team Shrimps, HCMUT, Viet Nam

Shrimp by-products are one of the causes of the environmental pollution. With 1 ton of finished shrimp, 0.75 tons of waste is discharged into environment. However, such by-products from seafood processing are valuable resources that are not exploited effectively. Replacing current chemical methods that burdens the environment in chitin and chitosan recovery from shrimp by-products, a zero-waste solution is proposed to use yeast as an addition to aquatic waste through biological method.

The microbiological approach produces Chitin and recovers protein from shrimp processing by-products by the yeast separated fermented pork rolls. Thus, it reuses by-products to collect and synthesize chitin for reuse in related industries, such as food and pharmacy, and reduces the waste amount in the environment.

6. ***Acceleration of Rural and Costal Electrification Process in Sabah via Implementation of Ocean Thermal Energy Conversion (OTEC) Technology***
Team OTEC Warriors (OTW), UKM, Malaysia

Sabah, Malaysia relies on fossil fuels for decentralized power generation, causing GHG emissions and environmental degradation. Despite the presence of renewables such as solar and micro-hydro powers, they account for only 7.3% of the total energy supply, leaving over 400 villages unelectrified due to fossil fuel dependency and limited grid access.

A new solution proposes an ocean thermal energy conversion (OTEC) system, leveraging Sabah's geographical advantage of warm tropical waters and deep oceanic zones. The OTEC system can generate up to 1 MW of electricity year-round by utilizing the temperature gradient between warm surface and cold deep seawater, while producing desalinated seawater. Aligning with SDGs, it can enhance energy security and provide clean energy for local communities.

Entrepreneurial Solutions

1. ***Innovative Algae-Based Oxygenation and Aesthetic Solution for Urban Spaces***
   Team Aqua Vitae, UKM, Malaysia

   Malaysia's urban areas face environmental challenges, particularly air pollution and diminished green spaces, which are largely attributed to industrialization and transportation growth. It introduces an innovative algae-based solution aimed at enhancing urban sustainability by integrating BCG models.

   This system involves cultivating microalgae in acrylic tubes attached to urban building facades, which, once matured, will be transferred to green walls to boost oxygen production and lower CO_2 levels. It can contribute to reducing urban CO_2 levels and improving public health with collaboration among municipalities, green technology investors, and urban planners. Such system has the potential to promote resource efficiency and support circular economy with its sustainability.

2. ***XOS EcoTech: Empowering Wellness with Sustainability***
   Team Gulla Gulli, Syarif Hidayatullah Jakarta Islamic State University, Indonesia

   The rising incidences of diseases such as type 2 diabetes and hypercholesterolemia highlight the need for effective health supplements, particularly xylooligosaccharides (XOS), which can be produced from Indonesia's abundant agro-waste. XOS, a prebiotic derived from hemicellulose, has been shown to improve health markers such as lipid profiles and glucose metabolism. The global market for XOS is projected to grow at a compound annual growth rate of 7%, increasing from USD 74 million in 2023 to USD 144.5 million by 2033 by growing health awareness.

   An introduced solution is to include personalized biomass optimization consultations and collaborations with healthcare professionals to enhance biowaste utilization. The production process aims to convert cellulose waste into biodegradable packaging and liquid waste into bioethanol, promoting sustainable development and creating new economic opportunities.

3. ***Bio-concrete***
   Team Verde, UKM, Malaysia

   The construction industry greatly contributes to GHG emissions and environmental degradation, primarily due to its use of traditional Portland cement. A proposed solution is the self-healing, zero-cement bio-concrete made from industrial wastes such as rice husk ash and fly ash, which are rich in aluminosilicates and able to form geopolymers as an eco-friendly alternative to cement.

   This bio-concrete includes bacteria *Sporosarcina pasteurii* that facilitate self-healing through calcium carbonate production, extending the material's lifespan and lowering maintenance costs. By utilizing industrial waste, the approach reduces landfill wastes and conserves non-renewable resources. It can transform the construction industry by fostering circular economy, minimizing environmental impact, and supporting net-zero emissions.

4. ***A Sustainable Paper Solution from Brewing Waste***
Team BIO4HUST, HUST, Viet Nam

A proposed solution for waste management in Viet Nam's beer production industry involves converting spent grains and by-products from brewing into eco-friendly paper products. With beer production reaching approximately 4.6 billion liters in 2019, this initiative could recycle hundreds of thousands of tons of spent grains, potentially producing around 10,000 tons of paper annually. This approach not only reduces waste and the need for virgin wood in paper production but also aligns with the BCG business model to create sustainable value. The solution is expected to cut down about 20,000 tons of GHG emissions each year, while also lowering costs associated with waste management and raw materials for beer and paper industries.

5. ***Unlocking the Potential of Corn: Agronomy, Applications, and Opportunities in the BCG Economy through Innovative Biojar and Biofertilizer Solutions***
Team ARUSHA, State University of Semarang, Indonesia

Ketaon, a village in Boyolali, a significant corn-producing center in Central Java, produces 123,135 tons in 2019 with a harvest area of 33,556.5 hectares in 2022. The local economy relies on corn farming, making the community vulnerable to economic decline if crops fail. The situation has led to an increase in corn waste, which is improperly disposed of, causing air pollution and health risks.

To solve the issues, the Corn-Based Creation initiative is introduced with focus on two products: Eco-friendly Biodegradable BioJar made from corn stalk waste and Organic Fertilizer from corn fronds. The former can be reused for planting, while the latter enhances crop quality. This initiative can promote green economic activities and reinvests profits back to the farming community with collaboration among local farmers, MSMEs, and organizations in the sustainable community.

6. ***Sustainable Agriculture Innovation: Sustainable Fertilization***
Team Hy-Tech, Diponegoro University, Indonesia

Thailand is experiencing a drought crisis due to extreme heatwaves and low rainfall, with temperatures up to 40°C, leading to water scarcity and crop failures. To address this issue, a solution – Paddy Silica Cellulose Fertilizer (Pasice) has been proposed, utilizing rice waste such as rice straw and husks, which are abundant in Thailand.

The Pasice is created through graft polymerization and chemical cross-linking, using potassium persulfate and Polyvinyl alcohol (PVA) to produce a hydrogel with a high swelling ratio and excellent water retention. The silica coating from rice husks enhances nutrient release and water retention, making Pasice particularly effective in drought conditions. Its slow-release mechanism allows for gradual absorption of nutrients and water by crops, promoting growth while reducing waste. The eco-friendly Pasice offers farmers a cost-effective and sustainable approach to crop management, ensuring higher yields despite challenging environmental conditions.

Figure 11. Participants, including young entrepreneurs and pitch reviewers, present at APEC Training Course. a. Team Verde, UKM, Malaysia**; b.** Team AquaVitae, UKM, Malaysia**; c.** Team Gulla Gulli, Syarif Hidayatullah Jakarta Islamic State University Indonesia; **d.** Team Hy-Tech, Diponegoro University, Indonesia; **e.** Tuan Anh Pham, HUST, Viet Nam; **f.** Ahmad Fathoni, BRIN, Indonesia (right) Thien Khanh Tran, GDU, Viet Nam (left)

Figure 12. Panelists and Speakers present at APEC Training Course panel discussions. a. Guang Wei JANG, ITRI, Chinese Taipei (left) and Rosibel Ochoa, UC-Riverside, the United States (right)**; b.** Nguyen Hong Quan, VNU-HCM, Viet Nam (left) and Yau-Jr LIU, APEC-SCMC, Chinese Taipei (right).

C. Key Takeaways: Demo-Site Best Practice

The Demo-Site Best Practice features technique and method demonstration at the adiCET, CMRU that allowed the participants to explore how the Green Synergy mechanism works with real applications to facilitate the sustainable development of a local community. Situated at the Mae Rim Campus of CMRU where energy conservation, higher efficiencies, and use of renewables is concerned, adiCET aims to be the learning center for green technologies to showcase real applications for sustainable living.

The adiCET features Chiang Mai World Green City as a living laboratory that provide best practice for CMRU staffs, students, scholars, and visitors. As adiCET strives to be the leading institution to promote and develop the technologies and management model for the betterment of the community, it is engaged in the integration of focus areas, such as renewable energy, green technology, environment protection, local wisdom and culture conservation for the local community of Asia and the world.

Photo 14. Experts and participants present at Demo-Site Best Practice at adiCET, CMRU.

OUTCOMES

The outcomes resulted from the outputs as the recommendations based on the key issues indicated in the Policy Brief formed at the Green Synergy Solutions Event. The recommendations of the APEC Workshop are key findings on green energy transition and BCG societal transformation for Net-Zero Emissions; and those from the APEC Training Course are key learnings on STI entrepreneurship and SME ESG practice.

I. APEC Workshop Recommendations

A. Key Findings: *Green Energy Transition in the Asia-Pacific Region*

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Kampanart Silva, NSTDA National Energy Technology Center (ENTEC), Thailand;
Guang Wei JANG, ITRI Material and Chemical Research Laboratories (MCL), Chinese Taipei

Highlights

1. Definition and Taxonomy for Green Energy

Consensus to be reached on the scope of green energy

The term green energy has been used for several decades without consensus being reached regarding the definition. Many economies strictly limit green energy to only renewable energy while other economies expanded the scope to cover nuclear power and natural gas. Before identifying key clean energy technologies to empower net-zero energy transition, it is essential to take a step back and discuss the definition of green energy to ensure the correct scope of technologies to be considered. This can also be in terms of common taxonomy.

A key component of the EU's framework for sustainable finance and an important instrument for market transparency is the EU taxonomy. Many economies are using the EU taxonomy, including Germany; France; Spain; Italy; the U.K.; and Canada, while other economies have developed their own sustainability taxonomies, such as, China; Colombia; Korea; Mexico; Russia; Singapore; South Africa; and Thailand. This taxonomy will support economic activities most needed for this transition by directing investments in alignment with the objectives of *European Green Deal* [**21**].

The taxonomy allows the non-/financial business to share common definitions of economic activities that can be considered environmentally sustainable. It plays a crucial role in helping economies scale up for sustainable investment by designing security for investors, protecting private investors from greenwash, supporting businesses turning climate-friendly, and mitigating market fragmentation.

2. **Promotion of Carbon Footprint Assessment and Carbon Credit Trading**
Carbon footprint assessment as the basic skills for all green energy holders/users, and carbon credit trading as the motivation for green energy promotion

In this century, the global GHG emissions reached approximately 52.96 GtCO2eq in 2023, an increase from 32.74 GtCO2eq in 1990, with the average growth rate of 1.2% per year [**22, 23**]. Asia-Pacific economies contribute more than 40% of global emissions, indicating the necessity to make efforts to reduce GHG emissions. The global community set a target at the COP 21 in Paris to achieve net-zero in the second half of this century. Economies have committed to achieving net-zero by 2050, including Brunei Darussalam; Bangladesh; Cambodia; Japan; Korea; Laos; Malaysia; Myanmar; Singapore; Sri Lanka; and Viet Nam. China and Indonesia have set their targets for 2060, while Thailand aims for carbon neutral in 2050 and net-zero emissions by 2065, and India has committed to the goal by 2070 [**24**].

In alignment with the global target, the Global Stock Take (GST) is conducted every 5 years to assess progress towards achieving climate goals, marking a critical turning point in global efforts to address climate change. Many mechanisms have been implemented to reduce the GHG emissions, including Clean Development Mechanism (CDM), Joint Implementation (JI), and Emissions Trading (ET) etc. These mechanisms are used across economies for GHG reduction support. Emission trading scheme (ETS) represents a market-based approach to controlling GHG emissions by offering economic incentives [**21, 25**].

One commonly known component of ETS is carbon credit. This should be accompanied by the promotion of the assessment of carbon footprint of product (CFP), which is crucial for evaluating energy consumption and waste creation, raising environmental awareness in people to understand the impact of their activities on climate change. In particular, the assessment of carbon footprint for organization (CFO) is also becoming a requirement for business, residential, and industrial sectors, which cover all scopes of carbon emission.

3. **Transition from Incentives to Standards and Regulations.**
Consideration of transitioning from incentive programs to standards and regulations when the technologies become mature and are diffused across the economies

Various mechanisms are used in many economies to support GHG reduction and SDGs. These mechanisms are often supported by subsidies and incentives designed to enhance adoption and effectiveness. However, governments are generally not in a position of continuously providing financial subsidies. Standards and regulations are essential to ensure that incentivized activities are getting the economies closer to the GHG emission reduction goals.

It is critical to offer incentives to encourage the use of green energy technologies and low-carbon investment since these actions often cannot be carried out successfully without incentivization. However, an enormous amount of budget is required for each economy to pursue incentive programs. Given that the capacity of green energy technologies entering the market will significantly increase, government incentive

program may not be a sustainable solution. At some stage, the government will need to consider transitioning from incentive programs to standards and regulations when the technologies become mature enough to diffuse across the economies.

Finally, the leading economies should play a pivotal role in supporting developing economies in their efforts to achieve net-zero targets. This support can be provided through investments in low-carbon technologies and the best practices, as well as the low-interest loans. Such financial assistance would help APEC economies transition to more sustainable energy systems and achieve their climate commitments, fostering both environmental and economic resilience in the region.

Discussions

1. **Environmental impact must be considered while advancing energy availability. Biomass valorization and recycling are keys to lower production costs.**
   The availability of energy supplies is a crucial matter, one with a major impact on not only daily life and wellbeing, but even on a macro level (e.g., domestic security). To ensure their availability, energy supplies must be provided at affordable prices. However, this endeavor requires addressing adverse environmental impacts — which often remain overlooked — while pursuing technological advancement and affordable supply. In the development of green energy technologies, it is critical to implement cascade valorization of biomass and/or the utilization of recycled materials as production fuel and chemicals to reduce production cost.

2. **Combining bioprocess technologies enhances product lines and performance. Bioenergy market development requires public-private sectoral coordination.**
   The integration of biomass and waste treatment technologies provides opportunities for boarding product lines and property performance to produce sustainable energy, chemicals and materials. The economic status quo often results in a discrete profit chasing and “not in my backyard” issues. An integrated supply chain collaboration is critical for the successful development of green bioenergy as an alternative to fossil fuels. While there are many potential opportunities in the emerging bioenergy market, for meaningful developments there remains the need to coordinate the efforts of various sectors, including those of resource providers, manufacturers, technology development institutes, and government policy makers.

3. **Technology upscaling necessitates integrative mechanism. Policy alignment supports bio-industries and standardizes biomass prices and carbon credits.**
   In addition to balancing the concerns of energy security and economic viability, the environmental impacts of production processes and product utilization should be taken into consideration. A whole life cycle assessment is a more accurate representation of product carbon footprints than is the current cradle-to-gate method. There remain great challenges for the upscaling of circular economy-related technologies in various stages to commercialization. Thus, it is critical to create a mechanism to facilitate networking and integration between stakeholders. It is also important for various government agencies to synchronize their policies to foster in the long-term sustainable bio-based industries and to standardize biomass prices and carbon credits.

4. **Circular economy entails effective waste product management that reduces carbon footprints. Contamination are challenges in using waste products.**
   A full cycle circular economy would rely on the visualization of waste products. Suitable product end-of-life management could contribute to a significant reduction of product carbon footprints. However, utilizing waste products or “scrubs” may prove challenging for certain products, such as health cares, fertilizers, and those used to store food. In the past, regulations that restrict or prohibit the use of waste products were established to avoid contamination and/or utilization of low-grade/unsuitable substances.

5. **Outdated regulations hinder bio-business growth. Cross-sectoral negotiation is needed to balance regulatory concern and technological development.**
   Many businesses — particularly those in smaller scale, such as SMEs and start-ups, tended to avoid utilizing waste products, to avoid time and money spent on navigating regulatory approvals and other requirements. However, outdated regulations may now be limiting the development of emerging biomaterials and bioenergy industries. It is thus crucial for industries to designate reliable representatives with proper channels to communicate with government agencies. In this regard, balancing regulatory concerns and tech developmental needs are necessary to achieve a circular economy model.

B. Key Findings: *BCG Societal Transformation around Southeast Asia*

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Hathaithip Sintuya, CMRU Asian Development Institute for Community Economy and Technology (adiCET), Thailand;
Nguyen Hong Quan, VNU-HCM Institute for Circular Economy Development (ICED), Viet Nam

Highlights

1. **Policy and Regulatory Frameworks**
   Commitment and Integration: Governments should implement clear, long-term policies that integrate with local, regional, and global frameworks, ensuring alignment with climate goals. Policies must be adaptable to technological advances and evolving economic landscapes, as seen in Australia’s robust bioeconomy initiatives.
   Consistency in Governance: To ensure continuity, there must be mechanisms for long-term commitment across changing administrations. *Philippine Development Plan* and *Queensland’s Biofutures Roadmap* could be policy models for long-term goals.
   Data-Driven Policy: In the Philippines, policies are emerging based on data gathering and stakeholder analysis. Governments should increase policymakers’ awareness and advocate for the adoption of forward-looking policies that drive the BCG model.

2. **Technological Innovation and Adoption**
   Innovation as a Driver: Technology is a key to BCG economy. Governments must foster the integration of precision farming, smart sensor, and AI-powered system that reduces emissions in agriculture and fisheries. Sandbox approaches of Thailand and Viet Nam can showcase examining new technologies before domestic application.
   Regulatory Sandbox: Economies should establish regulatory sandboxes to test and refine emerging technologies, such as precision agriculture and bioenergy technologies, before scaling them domestically. Pioneer zones should be identified where technological integration is first implemented, and results monitored over time.

3. **Circular Economy Practices**

   Waste Valorization: Circular economy practices should focus on converting agricultural and industrial waste into valuable products, reducing overall emissions. Malaysia and The Philippines have implemented industrial symbiosis and bioenergy in sectors like palm oil and rice farming, demonstrating the efficacy of circular models.

   Localized Innovation: Encourage economies to develop context-specific circular economy strategies, tailored to domestic industries and cultural practices, while sharing best practices globally.

4. **Public-Private Partnerships**

   Stakeholder Engagement: Successful BCG initiatives rely on collaboration between government, private sector, and social organizations. Governments should mobilize partnerships across levels such as local stakeholders and governments, as seen in the Philippines' engagement with agriculture institutions and women's groups.

   Synergy: The partnership between the government, private sector, and social community should be built on synergetic system, with all parties working toward a shared goal of achieving net-zero for mutual benefit.

   Best Practice Sharing: Public-private partnerships should foster the exchange of best practices across different sectors. Training programs and awareness initiatives should be rolled out to ensure partners understand their roles in net-zero transition.

5. **Education and Awareness**

   Capacity Building: Education should be a priority at all levels of society, from rural communities to universities, to build awareness and skills for the circular economy and technological innovations. In Thailand, education programs that integrate the circular economy at various levels have been initiated. In the Philippines, universities are playing an increasing role in capacity building for sustainable agriculture, and Viet Nam is developing interdisciplinary programs on circular economy and sustainability.

   Community Engagement: Programs should focus on engaging community leaders to raise awareness of the BCG economy's benefits. Efforts to increase capacity development, as requested by communities in Southeast Asia, should be implemented to ensure widespread understanding of sustainability practices.

6. **Financial Mechanisms and Incentives**

   Investment Mobilization: Governments need to develop financial mechanisms such as grants, carbon credits, and innovation funds that support the scaling of circular economy initiatives and technological innovations. Investment in bioeconomy sectors, such as precision fermentation in Queensland, Australia, should be encouraged.

   Incentivizing SMEs: SMEs should be supported with financial incentives and technical assistance to adopt sustainable practices toward green transition, particularly in industries like agriculture, waste management, and renewable energy.

7. **Global and Regional Cooperation**

   Harmonizing Standards: Global cooperation is essential for sharing technologies and aligning policies. Regional platforms, such as the GBA/UQ, should be strengthened for sharing innovations and benefiting from harmonized standards across economies.

Policy Alignment: Governments should ensure that bioeconomy research and technological developments align with broader global sustainability and trade policies, especially in regions like ASEAN where diverse regulations exist.

8. **Community and Cultural Engagement**
   Empowering Communities: Communities should be empowered to lead bottom-up sustainability initiatives, including engaging women, farmers, and workers in precision agriculture and waste valorization, benefiting society, economy, and environment.
   Cultural Sensitivity: Policy implementation should consider unique cultural and social contexts, ensuring programs are relevant and accepted in communities. In Southeast Asia, the programs should involve local leadership and participation for greater impact.

Discussions

1. **Economic Growth**
   Job Creation: Companies promote renewable energy solutions, such as wind, solar, and bioenergy. BCG businesses may create employment opportunities, particularly in renewables, sustainable agriculture, and waste management sectors.
   SMEs' Contribution: SMEs are at the forefront of developing green products and services and adopting BCG models for driving local entrepreneurship. By engaging in green activities, SMEs can drive regional economic growth through employment generation, ensuring that communities benefit from BCG principles directly.

2. **Community Development**
   Local Resilience: By adopting localized solutions, such as community-based renewable energy projects and sustainable farming by SMEs, BCG businesses strengthen community resilience against environmental and economic challenges.
   Marginalized Groups: Initiatives led by BCG businesses often prioritize inclusivity, supporting smaller enterprises such as SMEs that contribute to building resilient communities by aligning local economic activities with BCG principles.

3. **Education and Awareness**
   Sustainable Practices: Consumers and producers may lack sustainability awareness. BCG businesses could engage in awareness campaigns and education programs, encouraging individuals and institutions to adopt sustainable practices.
   Capacity Building: Educating platforms and programs for local businesses and communities enhance skills to adopt BCG in green practices effectively.

4. **Innovation and Technology**
   Green Technologies: BCG businesses drive technological innovation in renewable energy and waste management that lower environmental footprint.
   Joint Research: Partnerships between BCG businesses, academia, government entities, and international organizations could advance green technologies, such as renewable energy systems or waste management tools.

II. APEC Training Course Recommendations

A. Key Learnings: *STI Entrepreneurship*

Rosibel Ochoa, UC - Riverside, the United States;
Guang Wei JANG, ITRI Material and Chemical Research Laboratories (MCL), Chinese Taipei

Highlights

1. What problem or need to address?
2. How to define customer?
3. What to do to move technology to market?
4. Where to find resource for technology transfer?
5. What are key barriers to pitch success?

Discussions

1. **Addressing issues of customer identification, product clarity, and supply chain management can enhance innovative and entrepreneurial pitches.**
   In general, young entrepreneurial teams' pitch proposals struggle with clearly presenting expected customers and competitors (WHO), the target product (WHAT), and why the team chose a particular challenge (WHY). Young entrepreneurs need assistance for identifying technology/IP differentiation and business planning. They also overlook supply chain management, which is critical for business success. Other important considerations include HOW to control and manage feedstock, which may vary due to factors such as geography, and the influence of remote transportation and disaster-prone locations, which significantly impact feedstock price.

2. **Strategic target segmentation and continuous innovation are important for start-up success in product development.**
   Identifying a target segment on which to focus should not only commence early in the product development stage but should be an ongoing endeavor. Innovation should not be considered not only technology but also feasible business models. A successful business requires an assessment of one's own strengths and weaknesses, as well as those of one's competitors (e.g., identifying the applicable niches); ideally, a start-up's team members should be able to summarize the vision and mission of their business in a way that is easily conveyed to laypersons.

3. **SWOT analysis in business planning enhances entrepreneurial success.**
   Thus, a robust SWOT analysis — often overlooked by young entrepreneurs — is crucial. The foregoing considerations may prove indispensable for many aspects of a sustainable business, such as the inclusion of contingency plans in overall business plans or the formulation of a product development schedule (e.g., for mid/long-term products). As always, a well-organized team and expert assistance are necessary.

4. **Integrating networking supply chains to enhance carbon credit policy implementation for efficient upscaling production.**
   Proper implementation of carbon credit/tax policy could be critical for establishing a successful circular economy, one with both environmental and societal benefits. To

transition from a heavily subsidized industry to one that is profitable — all while reducing carbon emissions — there is an urgent need for bioenergy and green product sectors to create a mechanism for networking and integrating supply chain companies and their respective regions, which will help facilitate the technological development of efficient upscaling production. As these endeavors involve energy and food security concerns, clear and long-term governmental policy support is important, especially for fostering technical development and pricing feedstocks and carbon credits.

5. **Identifying issue and consumer appeal are keys for young entrepreneurship.**
   Young entrepreneurs should identify not only challenges but also problem source in questions. This will enable them to set up a viable business plan and target their consumers with precision. Successful entrepreneurs understand what characteristics of their offered products are most appealing to their consumers. For the survey and evaluation of prototypes, it is critical to provide suitable “test bed” facilities and experts.

6. **Bridging science and market for economic viability and consumer engagement in product development.**
   The journey to the market success of a product is often marked by a series of challenges. Economic viability is often overlooked by scientists. It is important to communicate with your consumers prior to planning technology development; this will help not only with the identification of the target consumers and their market needs, but also with calibrating technical development and product development strategies. Achieving proof-of-concept feasibility in laboratories, while exciting, is merely an initial step, after which a development team must deal with the challenge of pilot production for prototyping. The success of a project may hinge upon the identification of economically feasible processes and the allocation of suitable facilities.

7. **Ensuring commercial viability with flexibility, partnerships, and diversification in business development.**
   Following a successful pilot production, commercial viability will further require flexible product designs, resilient supply chains, and market entry strategies. To ensure a successful business development, it is important to establish a strong partnership between the private and public sections and design a fair mechanism for all stockholders. A viable approach to a challenge may not be reliable at a different time or in another situation or region; thus, flexibility is also the lifeblood of a successful business. A single product line in unlikely to result in a sustainable business. Thus, it is also important to develop contingency plans and formulate new product lines.

8. **Empowering young entrepreneurs by setting open-labs for hydrogen economy.**
   It is encouraging to observe young entrepreneurs seeking solutions to address climate challenges arising from economic development, while it is crucial that their endeavors be supported. In furtherance of this goal, APEC-ACABT could establish an Open-Labs, which is intended to bridge technology and business to facilitate regional cooperation. Its vision can be: *Green hydrogen economy for a healthier environment*; as for the mission: Prompting international cooperation to assist young STI talents in entrepreneurship. The Open-Labs should consist of a state-of-art facility for product prototyping and characterizations as well as a group of volunteer experts in processing engineering, accounting, venture capital, life-cycle-analysis etc.

B. Key Learnings: *SMEs' ESG Practice*

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Nguyen Hong Quan, VNU-HCM Institute for Circular Economy Development (ICED), Viet Nam

Highlights

1. What are ESG Key Components to MSMEs?
2. How to prioritize ESG components in economies?
3. How to proceed inner process as MSMEs?
4. What roles would government play if people and society were priorities of MSMEs in Just transformation?

Discussions

SMEs should adopt ESG practices by setting environmental goals, engaging positively with society, and establishing strong governance. Due to limited resources, government support is needed to enhance sustainability, transparency, and social responsibility. To achieve ESG goals, SMEs should adopt key steps: (1) Set goals and strategies ; (2) Build a dedicated team ; (3) Self-assessment ; (4) Data report ; and (5) Improvement . Chinese Taipei's policy strategies regarding SME just transition of green transition are based on Pathway to Net-Zero Emissions in 2050, in which green transportation, just transition, vehicle electrification, and zero waste in resource recycling are included.

1. ESG key components

- Environment: Including carbon emissions, resource efficiency, waste management, and the use of renewable energy. SMEs should set specific environmental goals and action plans.
- Society: Involving employee welfare, community engagement, supply chain management, and consumer rights. SMEs must ensure that their activities have a positive impact on society and actively respond to social needs.
- Governance: Including corporate transparency, board structure, risk management, and compliance. SMEs should establish a robust governance structure to promote transparency and accountability in decision-making.

2. ESG components prioritization

- ESG is becoming practices in listed companies though limited in SMEs
- Some entrepreneur companies with a focus on sustainability as well as high–demand exporting market (e.g. EU, US) put ESG in their strategies, business models
- Goverment add limited supports in helping SMEs achieving ESG goals

3. Inner process

- Including sustainabliity/ESGs to strategic level and transform the ESGs goals to action plan, business modes
- Approaching to government and others (e.g. NGOs, International insitutions) to ask for supports (e.g. training, consulting, funding) to support green transition
- Recruiting talents who have sustainability, multi-\inter-disciplinary background to develop and implement ESG–related strategy.

4. Roles of government

- Providing supporting initiatives for just transformation e.g. training, tax reduction, low-rate loans, public-private partnership
- Connecting different actors (NGOs, financial institutions, international development, etc.) to support SMEs
- Creating, and enabling innovation ecosystems to support SMSs in green transition
- Mainstreaming ESGs-related policies in exisiting ones (e.g. Net-Zero, Green Growth)

Figure 15. The executive team of APEC-ACABT – CEO Shu-Yii WU, Executive Secretary Chen-Yeon CHU, Project Manager Cheng-Han Michael LIU, and Project Secretary Hui-Chen Renee Chiu with experts and participants during the Green Synergy Solutions Event.

CONCLUSION

For capacity building, the project held the Green Synergy Solutions Event to promote state-of-the-art bioenergy technologies and BCG approaches for Net-Zero Emissions. The participants acquired practical viewpoints, knowledge, and experience for entrepreneurial solutions to improve the circumstances of social and environmental issues in their communities and economies. Through the capacity-building event, the participating APEC member economies obtained, maintained, reinforced, and cultivated capabilities to advance the net-zero policies and regulations for their future development. Participants such as youth, females, and groups with untapped economic potential will move closer toward an interconnected society with resilience, an innovative environment with sustainability, and an inclusive economic engagement for all.

The APEC Workshop, APEC Training Course, and Demo-Site Best Practice (Self-fund) have successfully built capacity for APEC member economies, especially developing economies, with knowledge, abilities, skills, and technical know-how in Green Synergy Solutions, which then is expected to improve the economic and social well-being of the people in the APEC region. Young entrepreneurs with MSME potential developed innovative solutions to the traditional energy transition toward cleaner, renewable, and green energy and entrepreneurial solutions to the societal transformation toward bio-, circular, and green economy. It will encourage entrepreneurship, innovation, and start-ups, empower MSMEs to recognize economic issues, and ensure their business competitiveness in the net-zero market. Moreover, as the economies' needed capacity is developing, the long-term effect of the above will benefit co-prosperity and intergrowth in a more resilient, sustainable, and inclusive future, allowing the project beneficiaries to advance the attending economies and even the connective community spirit across the APEC region.

To adapt the *Aotearoa Plan of Action – Human resource development and skills for the future* and *Environmental and climate challenges and natural disasters*, this project-based platform facilitated the communication for representative regulators and technology developers to transfer knowledge and experience on net-zero roadmap strategies, green energy technologies, and bio-/circular/green economic models to STI delegates and participants. Besides, it equipped young entrepreneurial trainees with expertise and skills in green innovation and entrepreneurship, encouraged them to propose technical and social solutions to tackle challenges in the net-zero transition, and ensured their abilities to apply and harness Green Synergy Solutions to improve environmental and social circumstance and fulfill sustainable livings in resilient communities and economies. The above effort has contributed to achieving the economic driver of the *Putrajaya Vision 2040 - Strong, Balanced, Secure, Sustainable, and Inclusive Growth*.

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