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Green Synergy Solutions for Sustainable Community on Agriculture Residue-Based Energy and Circular Economy

APEC Policy Partnership on Science, Technology and Innovation

June 2023

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ACRONYMS & GLOSSARIES

The names of public or private institutions referenced in this document do not imply the political status of any APEC economy

Acronyms used in this report:

ACABT	APEC Research Center for Advanced Biohydrogen Technology
BRIN	National Research and Innovation Agency
CMU	Chiang Mai University
CNR-IIA	National Research Council Institute of Atmospheric Pollution Research
EGNRET	Expert Group on New and Renewable Energy Technologies
EWG	Energy Working Group
FCU	Feng Chia University
MFU	Mae Fah Luang University
MOEA	Ministry of Economic Affairs
MOFA	Ministry of Foreign Affairs
NCHU	National Chung Hsing University
NDC	National Development Council
NISTPASS	National Institute for S&T Policy and Strategy Studies
NSTC	National Science and Technology Council
NYCU	National Yang Ming Chiao Tung University
PhilRice	Philippine Rice Research Institute
PPSTI	Policy Partnership on Science, Technology and Innovation
UKM	National University of Malaysia
VLU	Van Lang University

Glossaries used in this report:

Capacity Building	A subject of the APEC Economic and Technical Cooperation (ECOTECH) program that aims to help APEC's developing member economies achieve APEC's goals of trade and investment liberalization. (*source: APEC website*)
Green Synergy	A green symbiotic system for integrating all green growth technologies that will be complimentary, cooperative, and harmonic to factor X of productivity and resource-saving. For example, integrate renewable energy with heat and hydrogen storage without a battery system and then apply it to the smart grid with low costs.

1. OVERVIEW

Due to the climate change issue over the past decades, public and private sectors of APEC member economies have valued the development of alternative eco-friendly green energy. Green Synergy Solutions utilize biomass resources from agro-wastes for bioenergy generation. Through the process, bio-refinery converts biomass to biohydrogen and related products. The solutions reduce carbon dioxide (CO_2) from improper treatment of agro-wastes and promote economic development by building a bio-circular economy. This project includes two themes, “Bio-wastes to Green Hythane” and “Bio-circular Economy.” It aims to promote an eco-community by using abundant bio-wastes, such as corn straw, rice straw, sugar bagasse, and palm oil residue. These bio-wastes are rich in carbon, nitrogen, and phosphorus nutrients that could produce green hythane and bio-fertilizer through synergetic bio-refinery processes. The project events provided a platform to create and share innovative and affordable technologies that simultaneously minimize the environmental impacts and increase sustainability for recovery in the APEC region.

To enhance capacity building and to promote green synergy, this project made outputs such as outlined and complete Policy Framework Reviews and Green Synergy Solutions Events with the theme “Green Synergy Solutions for Sustainable Community on Agriculture Residue-Based Energy and Circular Economy.” Policy Framework Reviews presented the policy studies on “Bio-wastes to Green Hythane” and “Bio-circular Economy.” 2022 Green Synergy Solutions Events included Policy Dialogue, Workshop - Lectures, Workshop - Young Entrepreneurs Training Program, and On-site Technical Practice (Self-fund). The hybrid events were on-site in Taichung and Nantou and online via Cisco WebEx. The overseas participants who were unable to travel attended the online meeting. During 15-17 September 2022, 51 participants, including speakers and experts, were present at Policy Dialogue; 51 at Workshop I; 72 at Workshop II; and 26 at On-site Technical Practice. The participants are from 12 APEC member economies such as Australia; Canada; China; Indonesia; Japan; Korea; Malaysia; The Philippines; Russia; Chinese Taipei; Thailand; Viet Nam; and a Non-APEC member (Italy). The gender target of female participation reached 30-50% for 2022 Green Synergy Solutions Events.

2022 Green Synergy Solutions Events provided a platform for the APEC economy delegates, speakers, experts, and participants to exchange opinions on theories and technologies of agriculture residue-based energy and circular economy. The events also let participants from the APEC region understand the green synergy demands and applications in APEC member economies under various circumstances. As challenges varied among economies, participants discussed and figured out possible and potential solutions to the current environmental and social issues, which built the capacity for participants by knowledge and experience of green synergy. As the government officials, scholars, specialists, and young entrepreneurs (including undergraduates, graduates, postgraduates, and staffs of MSMEs) from academia, research institutes, and public and private sectors shared their perspectives in the panel discussion, they came up to provide policy recommendations concluded in Policy Dialogue, disseminate the knowledge and experience delivered in Workshop, and thus furtherly enhance the connectivity in the APEC region. To consolidate and accelerate the subsequent improvement, outcomes, comments, and suggestions of this event related to this field have to go through examinations.

2. PROJECT IMPLEMENTATIONS AND OUTCOMES

APEC ACABT held project events with the theme “Green Synergy Solutions for Sustainable Community on Agriculture Residue-Based Energy and Circular Economy” to build capacity for the participants from APEC economies. The events aimed to promote sustainable growth, solve social and environmental issues, and make policy recommendations regarding Green Synergy Solutions for public and private sectors in the APEC region. During the events, the participants learned about the current development of the bio-wastes to green energy and circular economy. They acquired more ideas and information on the historical and prospective evolution of green energy policies in reviews and recommendations from Policy Dialogue, green synergy theories and technologies that feature state-of-the-art engineering in Workshop, and the HyMeTek knowledge and experience in On-site Technical Practice that are applicable in the APEC region. Please refer to the agenda in **Annex I** for more details on the events.

2.1 GREEN SYNERGY SOLUTIONS EVENTS

Despite the COVID epidemic, APEC ACABT held the 3-day hybrid Green Synergy Solutions Events with local and oversea participation. The experts of Policy Dialogue on “Bio-wastes to Green Hythane” and “Bio-circular Economy” shared their viewpoints on the current development of their economies, which became a foundation for policy recommendations. Extended from Policy Dialogue, Workshop I - Lectures had more relative theories and techniques applied in the professional field of green synergy. The participants learned from relevant knowledge fields for more innovative solutions. Workshop II - Young Entrepreneurs Training Program provided youths with opportunities to solve social and environmental problems. Through this program, they demonstrated their creativity and care for their communities. The On-site Technical Practice was a demo-site visit to the ecological farm with an anaerobic fermentation tank. It enabled the participants to understand the mechanism of the HyMeTek, an application of green synergy that increases agricultural production and reduces agro-waste generation. The events built participants’ capacity with knowledge and experience to promote green synergy solutions and guided them to solve problems for their economies.

2.1A POLICY DIALOGUE

During Policy Dialogue, **Prof. Dr. Shu-Yii WU,** the CEO of APEC ACABT; **Mr. Chih-Cheng YEH,** the Chinese Taipei NSTC’s Director General; **Mrs. Ying-Ming WONG** the MOFA’s Director General; and **Mr. Winky Angga Priatna** the Director of Industry Department of Indonesia Economic and Trade Office to Taipei; all gave an opening speech to the offline and online participants (**Figures 1. & 2.**). Given the economy’s entry restriction policy, overseas participants could not be present. Although, they still joined us via virtual meeting and took group photos with those at the avenue.

Figure 1.
On-site distinguished guests at InSky Hotel located in Taichung.

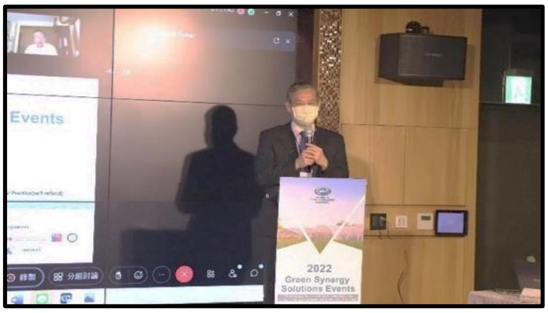

Figure 2.
Project Overseer, Prof. Dr. Shu-Yii WU gave the opening speech.

In Session I, **Dr. Doan Trinh TA**, an independent expert on STI issues (Viet Nam), shared the current net zero policy in Viet Nam. He also talked about the commitment to Net-Zero Emissions by 2050 and phasing out coal power generation by 2040 (**Figure 3.**). Representing Indonesia, **Prof. Dr. Eng. Eniya Listiani DEWI**, a Research Professor from BRIN (Indonesia), presented the recent establishment of the Hydrogen Circular Economy in Indonesia. During the presentation, she talked about Indonesia's biodiversity and circular hydrogen economy for sustainable energy (**Figure 4.**).

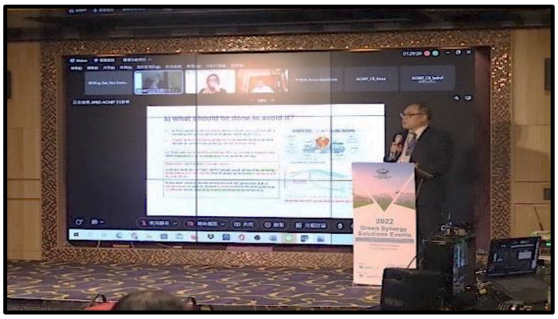

Figure 3.
Dr. Doan Trinh TA from Viet Nam delivered his presentation.

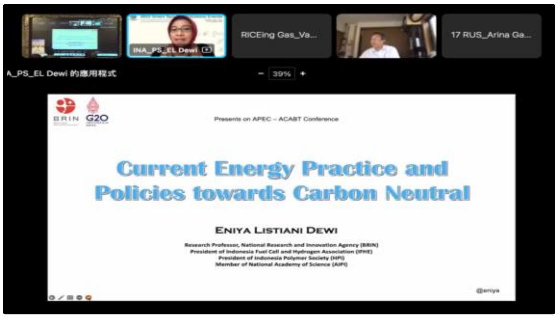

Figure 4.
Prof. Dr.-Eng. Eniya Listiani DEWI from Indonesia delivered her presentation.

In Session II, **Dr. Panate MANOMAIVIBOOL**, an assistant professor from MFU (Thailand), delivered his speech regarding the circular economy model on tourist islands. Moreover, he shared his research on resolutions of recycling operations to secure the islands' environment. Next, **Dr. Hazel B. ALFON**, a DBA candidate from PhilRice – Central Experiment Station Maligaya, Science City of Munoz (Philippines), introduced the optimization of the circular economy for rice farm communities. The last speaker of Session II, **Dr. Pruk AGGARANGSI** from Energy Research, and Development Institute Nakornping, CMU (Thailand), shared his experience in carbon neutrality at CMU Demonstration Area. During Session III - Panel Discussion, **Prof. Dr. Bing-Chwen YANG** from NYCU and **Prof. Dr. Chun-Hsiung HUNG** from NCHU (Chinese Taipei) moderated the panel discussions with the speakers and participants. They extended and deepened the issues, which allowed the audience to know more about the green synergy policies. Discussed details are as follows.

Dr. Doan Trinh TA discussed the current net zero policy in Viet Nam. The motivation for the Viet Nam government is to pledge a goal for Net-Zero Emissions by 2050 and phase out coal power generation by 2040. Viet Nam is seriously affected by climate change. The threat is extremely harsh on the developing APEC economies that need investment boosts with international support on finance and technology.

Prof. Dr. Eniya Listiani DEWI talked about the hydrogen-circular economy establishment in Indonesia. Similar to the circumstances in Viet Nam, the Indonesian government is accelerating the energy transition toward Net-Zero Emissions by 2060. The challenge of usage reduction of traditional power, such as coal, diesel, oil, and gas, is hard to conquer. A possible solution is to convert oversupplied electricity for hydrogen gas production from water and store hydrogen gas in other energy carriers. International support on hydrogen storage, batteries, and carriers is needed. With a decentralized and optimized approach, a sustainable energy transition would be achievable in Indonesia.

Dr. Panate MANOMAIVIBOOL introduced how to overcome the bottleneck for the circular economy on tourist islands. There was a hypothesis that the cost of transportation put a limit on recycling. A pilot study found that more waste materials could head to recycling sites by reducing shipping costs to junk shops. The next project phase is to improve recycling operations and community engagement.

Dr. Hazel B. ALFON discussed optimizing the bio-circular economy for rice-based farming communities. A real-time business model was used to determine the critical success factors to institutionalize the bio-circular economy, especially among marginalized farmers in geographically isolated and disadvantaged areas. A discussion was about how to get the rice-producing community to participate in the goal by actively contributing to the knowledge-building efforts. Specifically, the action research initiatives are about making farmers adopt the principles of the bio-circular economy that customize programs based on community assets (skills, competencies, natural resources, etc.). The approach is under the premise that the farmers are the primary partners in sustainable local economic development. The participation of the farmers might be the most critical point because agriculture is the primary livelihood in most parts of the Philippines. Thus, the Philippine experience could be a case study for APEC members that rely on agriculture as their main economic base. Dr. Alfon is now expanding her initiatives by developing methods to facilitate the adoption of the bio-circular economy, which other peers in APEC economies could consider in the future.

Dr. Pruk AGGARANGSI proposed a discussion on a carbon neutrality case study using CMU as an example. The campus has agriculture, food processing, a business community, and a residential area. Through Bio-Circular-Green (BCG) economy concept, the smart energy design and environmental management will help CMU achieve the goal of a 2023 carbon-neutral community in the demonstration area.

Finally, **Prof. Dr. Jun MIYAKE**, a senior scholar from Osaka University (Japan), questioned the energy cost that may affect Chinese Taipei's pursuit of terminating nuclear power plants by 2025. Nowadays, the electricity generated from nuclear power only accounts for about 8%, a value equal to the sum of those from solar and wind power in the economy. With more installments of green energy production, the 2025 goal of abandoning nuclear should be feasible.

Overall, it was an informative panel discussion from different APEC members on how to march toward Net-Zero Emissions. There was a discussion about the carbon-capture status of APEC members. Carbon by forests as well as soil might be current hot approaches. Another discussed issue is involving more community members in these energy plans and modifying the government's plan to fit different areas.

Figure 5.
The moderators, Prof. Dr. Bing-Chwen YANG (Left) and Prof. Dr. Chun-Hsiung HUNG (Right) from Chinese Taipei were exchanging viewpoints in the panel discussion.

2.1B WORKSHOP I - LECTURES

APEC ACABT invited experts to share their knowledge or experience based on their expertise in “Bio-wastes to Green Hythane” and “Bio-circular Economy.” The speakers have academic backgrounds in green synergy science and technology. They presented the retrospective and prospective circumstances of APEC economies based on their studies. Besides, they highlighted domestic green synergy demands, applications, and possible or potential solutions to the relevant issues for each economy.

In Session I, the first speaker, **Prof. Dr. Udin HASANUDIN,** University of Lampung (Indonesia), discussed his analysis of biogas technological development through a case study from a specific consortium of microbes to biogas utilization (**Figure 6.**). **Dr. Peer MOHAMED** from UKM (Malaysia) gave a talk on palm oil waste biomass management for renewable energy through a combination of biological membrane systems (**Figure 7.**). Then, **Dr. Thien Khanh TRAN** from VLU, Viet Nam, introduced ocean hydrogen by eco-friendly methods in Viet Nam and elaborated on suitable relevant policies.

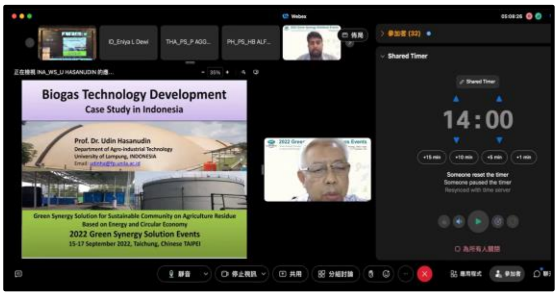

Figure 6.
Prof. Dr. Udin HASANUDIN from Indonesia delivered his presentation.

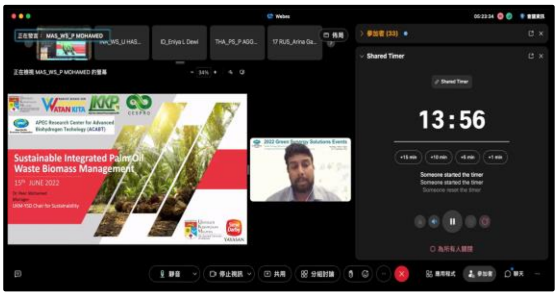

Figure 7.
Dr. Peer MOHAMED from Malaysia delivered his presentation.

In Session II, **Prof. Dr. Jin-Seek CHOI**, Hanyang University (Korea) presented the topic of edge/cloud-aided agents for cooperative energy management. Secondly, **Dr. Megan ARGYRIOU** from Climatworks Centre (Australia) shared her study on how climate action and socioeconomic development could be achievable simultaneously (**Figure 8.**). **Dr. Francesco PETRACCHINI** from CNR-IIA (Italy, Non-APEC member) addressed the challenges imposed on islands by human activities. Lastly, **Prof. Dr. Gopalakrishnan KUMAR** from Yonsei University (Korea) introduced Lignocellulosic Biorefinery, which accesses biofuels and bioproducts formation via biorefinery perspectives. Afterward, he hosted the panel discussion for Session III, which allowed the speakers to discuss with the participants on the lectures, helping them better understand green synergy technologies and their applications **(Figure 9.**).

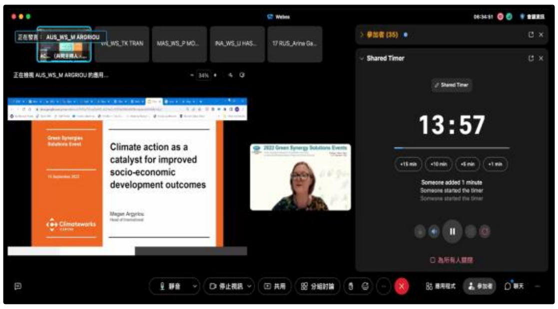

Figure 8.
Dr. Megan ARGYRIOU from Australia delivered her presentation.

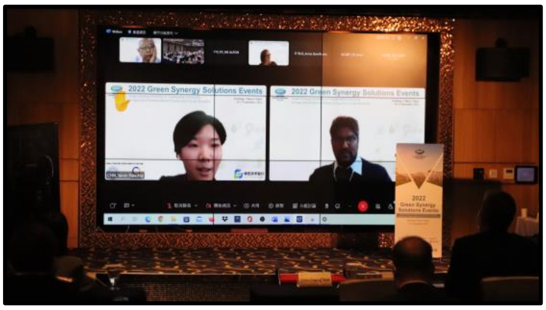

Figure 9.
Prof. Gopalakrishnan KUMAR (Right) from Korea delivered his presentation and hosted the Panel Discussion.

2.1C WORKSHOP II - YOUNG ENTREPRENEURS TRAINING PROGRAM

On the second day, APEC ACABT held the physical and virtual Training Program for the young entrepreneurial teams from 7 APEC economies. In July 2022, 32 teams submitted their Concept Notes to register for the event. In the early-September, reviewers selected 10 teams to attend Workshop II to present their final entrepreneurial solutions on 16 September 2022. 10 experts attended as reviewers on the final teams' presentations. They are **Prof. Dr. Dwi SUSILANINGSIH** (Indonesia), **Prof. Dr. Jun MIYAKE** (Japan), **Dr. Yeit Haan TEOW** (Malaysia), **Prof. Dr. Alissara REUNGSANG** (Thailand), **Dr. Kim Anh TO**, **Prof. Dr. Doan Trinh TA** (Viet Nam), **Prof. Dr. Jin Seek CHOI** (Korea), **Prof. Dr. Chy How LAY**, **Dr. Hoang Jyh LEU**, and **Dr. Ju Chuan WU** (Chinese Taipei) (**Figure 13.**).

In Session I, the first to deliver the presentation was **Team Lima Kaki** (Malaysia). They pointed out that sanitary pads made out of plastic could cause pollution, and addressed the resolution which is revolutionizing the menstrual hygiene industry to ensure sustainable consumption and production. **Team ChiTom** (Viet Nam) proposed recovering chitin from the shrimp by-products and then fabricating chitin into nano-chitin. In this regard, the impacts might mitigate the climate change crisis and reduce chemical and water use. **Team Giao Wao Deyimia** (Chinese Taipei) shared their ideas from agro-waste rice straws to value-added facial masks in tempt to achieve socioeconomic benefits, including carbon neutrality, circular economy, air quality improvement, and curbing global warming (**Figure 10.**). **Team Biogasverse** (Indonesia) presented an integrated biogas power plant on a farm for cacao and deer. The biogas production system applies agricultural residue-based energy to green synergy technologies in farm communities. At the beginning of Session II, **Team DTH** (Viet Nam) delivered their presentation focused on chitin production and protein recovery from shrimp processing by-products using Yarrowia lipolytic yeast. They proposed co-fermentation, an eco-friendly method, to make revenue from chitin sales and reduce waste consumption (**Figure 11.**). **Team RICEing Gas** (The Philippines) addressed the climate crisis by turning bio-waste products into available clean energy. It prevents air pollution and helps socio-economic development. The next team was **Team Bi Bi Dan** (Chinese Taipei). They found biochar a terrific solution to agro-waste and thought of an idea, eco-boba. The manufacturing process could be an alternative to domestic water purification systems.

Figure 10.
Team Giao Wao Deyimia from Chinese Taipei delivered their final presentation.

Figure 11.
Team DTH from Viet Nam on the stage for their final presentation.

In Session III, **Team Holeless Donut** (Thailand) discussed the topic of bioenergy and bioproducts derived from sugarcane waste in Thailand. They emphasized the objective of a technological process for electricity generation from gasification and biomass production. The next was **Team FIVE UKM** (Malaysia) which introduced the bioelectrochemical system with marketing strategy and analysis for this project. With different actions, we can easily understand how they will implement the BES of rural areas, specifically for APEC economies. Finally, **Team Lomonosov_MSU** (Russia) displayed a mobile swimming robot through videos, sharing the functions of the mobile system with the mathematical model and experimental prototype as solid evidence.

Figure 12.
Team Biogasverse, Indonesia, received the First place award from APEC ACABT's CEO, Prof. Dr. Shu-Yii WU (Far left), and APEC ACABT Committee member, Dr. Doan Trinh TA (Far right).

Figure 13.
Online and On-site reviewers on presentations for Workshop II - Young Entrepreneurs Training Program.

As Workshop II ended, the reviewers discussed and decided on the teams' ranking. **Team Biogasverse** (Indonesia) won First place (**Figure 12.**). **Team ChiTom** (Viet Nam) and **Team Lima Kaki** (Malaysia) won Second place. **Team Lomonosov_MSU** (Russia), **Team Giao Wao Deyimia** (Chinese Taipei), and **Team Holeless Donut** (Thailand) won Third place. The other four teams had Honorable Mentions.

Figure 14.
On-site and online participants of the young entrepreneurs training program.

During the event at InSky Hotel, 7 APEC economies participated physically and virtually, including Indonesia, Malaysia, Russia, Chinese Taipei, Thailand, The Philippines, and Viet Nam. Statistically, half of the participants are females. The event ensured the participation and engagement of both men and women to achieve gender equity.

2.1D ON-SITE TECHNICAL PRACTICE (SELF-FUND)

The technical practice participants explored how the circular mechanism works to produce biofertilizer, which increases agricultural production and decreases agro-waste. A circular economy farm based on natural farming and anaerobic digestion technologies enabled the participants to know the idea of circular economy, the theories of anaerobic digestion, and their field applications. The farmer introduced the practical demo site and their implementation of bio-circulation. The anaerobic digestion system turned the agro-waste into biogas, applicated in a generator and a stove for usages of public lighting and cooking, respectively. Through this activity, the participants can learn more about bioenergy applications and understand how to realize this model in their economies to solve environmental and social issues.

Figure 15.
Technical practice in the Eco-farm.

Figure 16.
Inrtoduction of HyMeTek at the demo-site.

During the COVID-19 epidemic, it was a success for the 3-day hybrid 2022 Green Synergy Solutions Events with local and overseas participation. The experts of Policy Dialogue shared their viewpoints on “Bio-wastes to Green Hythane” and “Bio-circular Economy.” They exchanged their opinions and observations on current and further development in their economies, which contributed to making the policy recommendations. The scholars of Workshop I – Lectures provided applicable theories and techniques in the professional field of green synergy. The participants learned from relevant knowledge fields for more innovative solutions. The Workshop II – Young Entrepreneurs Training Program allowed youths in the APEC Region to find solutions for social and environmental problems based on green synergy. Through this program, they demonstrated their care and creativity for their communities. The On-site Technical Practice at the demo-site ecological farm enabled the participants to learn the application of the HyMeTek that reduces agro-waste and produces green energy. Moreover, the participants explored how the circular mechanism reuses bio-fertilizers that increase agricultural production. Last but not least, the experience might inspire the participants to have innovative but practical ideas to carry out green synergy in their economies. In conclusion, with the organizing members’ engagement in capacity building, networking, and gender equity (**Figure 17.**), the project events have successfully promoted Green Synergy Solutions for Sustainable Community on Agriculture Residue-Based Energy and Circular Economy among the on-site and online participants from the APEC region.

Figure 17.
Event ceremony. Project Overseer of PPSTI 06 2021A and CEO of APEC ACABT, Prof. Dr. Shu-Yii WU (Second row, third from left); Executive Secretary of APEC ACABT, Prof. Dr. Chen-Yeon CHU (Second row, third from right); Project Manager of APEC ACABT, Mr. Cheng-Han Michael LIU (Second row, second from left); Project Secretary of APEC ACABT, Ms. Hui-Chen Renee CHIU (First row, far left). (Source: Mr. Yu-Hsuan CHIANG, Event Coordinator).

2.2 OUTLINED POLICY FRAMEWORK REVIEW

In the project, the two leading researchers explored the issues that required attention and changes at the governmental level from their perspectives on policies, technologies, and research. APEC ACABT had Prof. Dr. Chun-Hsiung HUNG and Prof. Dr. Bing-Chwen YANG, the two experts in the fields of “Bio-wastes to Green Hythane” and “Bio-circular Economy” respectively to be the leading researchers. They drafted Policy Framework Review as a reference for making policy recommendations at the Policy Dialogue Panel Discussion. Please refer to the Complete Policy Framework Review in **Annex II** for more details.

2.2A BIO-WASTES TO GREEN HYTHANE

BACKGROUND

Bio-wastes from small-scale agricultural operations hardly cause environmental concern as they could easily convert back to nature as fuels or composts/fertilizers. However, since the farming approaches are becoming highly concentrated on a large scale with advanced technique support, the fast-growing amount of bio-waste production has gradually become a globally significant concern nowadays. The twenty-one APEC member economies have different agricultural patterns along with distinct climates. These differences affect agriculture production because it depends on specific climate conditions. Therefore, the characteristic of bio-wastes produced differs significantly among APEC members. Conversion of bio-waste into biohythane must take the above into account.

FOCAL POINTS

a. Current regulations of the circular economy related to agro-waste management

Livestock wastes are collected for anaerobic digestion to reduce waste concentration and pollution. It comes before the land application of digested residuals as organic fertilizers to produce new agricultural products. Biogas like hydrogen and methane fuel the generator to provide electricity for the usage of the farm community, and then a complete cycle occurs. Therefore, regulations on carbon footprint and agro-waste management should be a part of the policy recommendations.

Chinese Taipei

To cultivate economic development and industrial transformation, the government proposed the “5+2 Innovative Industries” as the core of its industrial policy. Under this policy framework, the Council of Agriculture (COA) and the Environmental Protection Agency (EPA) stepped forward to encounter carbon footprint and agro-waste management. In 2019, COA established a specific project office, the Office of Climate Change Adjustment and Net-Zero Emissions, and set up the office’s working objectives to promote agricultural adjustment, mitigate the greenhouse effect, and other related measures. At the same time, the EPA set relevant regulations to enforce renewable energy developments, with an emphasis on establishing anaerobic digestion plants. In addition, EPA ensured that no carbon was released into the atmosphere by open-field incineration to reduce air pollution.

Viet Nam

With the proposal of a combination of further economic growth with environmental sustainability and better carbon footprint management, the “Viet Nam Green Growth Strategy (VGGS)” obtained official approval in 2012. Agro-waste management for ecological agriculture and sustainable development has become a main concern for the Viet Nam government. The authorities and organizations in Viet Nam are nowadays paying much more attention to the means of recycling agricultural wastes and residuals.

b. The modification and suggestions on carbon emissions management will allow the bio-wastes materials to become sustainable resources

In times of depleting resources, there is a quest for carbon emission management solutions in a circular economy. Bio-wastes such as agricultural residuals, livestock manures, and kitchen wastes attract increasing global attention to their conversion to sustainable resources. At the same time, it reduces greenhouse gas emissions for carbon neutrality.

Chinese Taipei

The policy-planning body of strategic development, NDC, announced the “2050 Net Zero Emission Roadmap” in 2022. “Hydrogen” and “Resource Circulation and Zero Waste” are the developmental strategies related to Bio-waste to Green Hythane. According to the above framework, the authority will modify the carbon emission management plan by shifting to a low-carbon economy by utilizing proven and mature green energy and carbon-reducing technologies. The government will continuously facilitate biogas utilization from agricultural waste, animal husbandry manure, industrial waste, and wastewater treatment plants by Renewable Energy Development Act.

Viet Nam

As part of the VGGS, Viet Nam has established a series of greenhouse gas emission reduction and related targets based on studies of sectors with high emissions, such as the energy, forestry, and agriculture sectors. Nowadays, there is a gap between the potential of agro-waste and residual recycling. Modifying carbon emission or bio-waste management is an essential need by the Viet Nam government and functional organizations, especially in collecting this agro-waste to produce energy.

c. Comparison of the carbon and resource supply management regulations to the biomass promotional objective, and its further limitations on the green hythane promotion

Any economy needs to increase its energy resource supplies and alternatives. Especially for most APEC member economies, the energy's diversity is so finite that they need additional energy imports. Regulation optimizations on carbon and resource supplies to promote biomass conversion into biofuels and bioenergy must be in consideration.

Chinese Taipei

Despite the solar and wind power, the government still faces a challenge to find a steady energy alternative to make up the 20% renewable energy goal by 2025. One of the solutions for promoting biohydrogen and biomethane production in the economy is the horizontal connection between government agencies such as the MOEA, the EPA, and the COA.

Viet Nam

There is considerable agro-waste from both planting and livestock discharged into the environment, which needs better carbon and resource supply management. The policies should reform to help different types of farms comply with existing environmental standards.

2.2B BIO-CIRCULAR ECONOMY

BACKGROUND

Because of the global environmental deterioration, the world reached a consensus on carbon neutrality. Most economies have also taken corresponding measures to reduce carbon emissions and slow down the continuous deterioration of the global environment. Among these measures, the recycling and reuse of limited resources are relatively important. Appropriately using Earth's resources can reduce environmental changes caused by overconsumption. Especially for recycling and reusing biological resources can be helpful for our environment since it has the advantage of simple conversion by the existing technology. Besides, it is able to reduce the resource waste for long-term waste treatment. Thus, all these efforts can protect our environment.

Agriculture accounts considerably for economic activities in the 21 APEC economies. Most economies are undergoing relatively rapid economic development, the demand and expenditure on various resources are relatively high. They must implement technologies for recycling biological resources in different stages to maintain our environment while pushing forward the economic development in the APEC Region. It will lead to a need for concept implementation of the bio-circular economy. It means that bio-wastes can convert into carbon-free energy or products with higher economic value through a technological introduction.

FOCAL POINTS

a. Analysis of the promotion mode of circular economy strategy

Taking Chinese Taipei as an example, the circular economy promotion comes from the five plus two innovative industries announced in 2016. In March 2022, the authority announced the carbon reduction path to match the global trend of 2050 Net-Zero Emission. “Resource recycling and zero waste” was one of the key 12 strategies in this path. It demonstrated the authority's determination to pursue environmental sustainability and highlighted the importance of a circular economy. Under this strategy, the various action plans and supporting measures developments have become a major driving force in facilitating the bio-circular economy and the creation of innovative industries. The main measures for the above included the following items:

1. Promoting the bio-circular technologies and innovational development on biological materials to facilitate the formation of new bio-related industrial chains;
2. Promoting green consumption and green transactions to create recycling industries;
3. Promoting energy resource integration and industrial symbiosis to create opportunities for the energy resource integration industry through incentive policy;
4. Promoting a technical demonstration zone for biological recycling and bio-waste reuse for the concrete presentation of the realization method and the benefit evaluation.

b. Discussion on the carbon reduction benefits and promotion of the bio-circular economy

In terms of the bio-circular economy, a biological cycle is distinct from an industrial cycle. It takes a shorter time to exert its benefits. What the biological cycle directly benefits is its waste reduction. The system utilizes biomass in ecological regeneration, which generates no or less garbage. As a consequence, it can be so-called “Waste turned into gold.” In other words, biological materials can become another potentially valuable (by-) product through value addition and business creation.

Therefore, a concept of a biological cycle is the flow of bio-related materials in nature. Products should be able to return to nature and become new resources after going through reuse and re-process. It reduces the waste of various resources on the Earth and the required energy for waste treatment. Some bio-wastes can still turn into energy through re-process and re-treatment. In other words, bioenergy, such as the biogas generated from pig waste, can become a fuel source for power generation.

The framework of the bio-circular economy involves a wide range of areas such as waste reduction, waste recycling and reusing, industrial integration, and industrial chain formation—such as comprehensive and cross-disciplinary promotion. In addition to research and development on new recycling technologies, carbon reduction benefits should also be evaluated and analyzed. Then, the possible preferential measures and relevant regulations should be structured to facilitate the industries to follow, creating the possibility for the new formation of an industrial chain.

2.2C POLICY DIALOGUE TOPICS AND RECOMMENDATIONS

BIO-WASTES TO GREEN HYTHANE

a. Hydrogen, methane, or mixed biogas

Anaerobic digestion of organic wastes has been well-studied. Two separated microorganism groups are for converting organics to hydrogen with VFAs (volatile fatty acids) and finalizing the reaction to produce methane. The two groups of functional microorganisms have distinct growth conditions, such as pH and retention time. Simple one-stage reactors from production to methane have worked throughout food industries and wastewater treatments. Hydrogen gas is greener energy than methane. Thus, the two sequencing reactors are designed by separating the hydrogen and methane production stages or stopping digestion after hydrogen production. The above has drawn attention to fulfill the different requirements.

Therefore, the authorities must implement the recommended policies of developing hydrogen, methane, or mixed biogas in each APEC member economy before they promote bio-waste digestion. It will significantly affect the process design and further requirements on gas-to-electricity production.

b. Maintaining the stable gas production by co-digestion with other organic wastes

Biogas production by only using agro-waste is not an ideal design. Crops' growth must follow their seasonal requirements. There is an extremely high amount of produced crop waste after the harvesting season. In other words, there could be times when anaerobic digesters receive no crop waste-feeding material for biogas production.

There should be a policy for the co-digestion of crop waste with other organic waste collected stably over time. Livestock wastewater is a possible and potential candidate for this purpose. Related policies must include waste transportation, odor control, and process design for co-digestion.

c. Carrot and stick

Open space crop waste incinerations have been a severe air pollution problem in many economies. The EPA in Chinese Taipei has applied new technologies, such as drone inspection and infrared sensing, and achieved significant case reduction. There should be strict policies and fines on banning crop waste incinerations, followed by acquiring the crop waste as feeding material for anaerobic digestion centers. There should be one more policy for promoting the green electricity market. It can be achievable by either FIT (Feed-in Tariff) or Renewable Portfolio Standard (RPS) that stimulates the marketing of biogas from bio-waste.

BIO-CIRCULAR ECONOMY

a. Reuse of waste food materials - how to reduce food crisis by making full use of food materials

The dialogue focus of future development and public education will be on the "upcycling" of the waste food or the regeneration, that is, the use of discarded waste food to regenerate new food. The "upcycling" of food waste reduces bio-related waste. It is a new way for food industries to deal with waste ingredients and creates new business opportunities. According to a report published by London Market Consultancy - Future Market Insights (FMI) in 2019, the estimated global market for leftover food is US$46.7 billion. The amount is increasing at a compound annual growth rate of 5%.

This new development for “Upcycling” food also exhibited the creativity of the food industry in production and processing, bringing more valuable new products into the market and contributing to the sustainable development of the environment. In other words, it is an innovative business opportunity under the bio-circular economy.

b. Differences in the utilization of biomass energy and fossil energy - how to avoid the potential harm of biomass energy to original fossil energy facilities

The dialogue will focus on future development and public education efforts on making characteristics of bio-energy match those of existing fossil energy as much as possible from the production process of bio-energy. On the other hand, it is necessary to discuss the change in the long-term maintenance and operation methods for various energy facilities to avoid problems in the operation of the facilities and reduce people's confidence and willingness to use bio-energy.

c. Impact of the bio-circular economy on people's livelihood - how to reduce people's doubts about recycling

The dialogue for future development and public education can focus on issues related to people's lives, such as how to show the flow of waste food materials through information platforms, the role of incinerators in the cycle for energy and environment, and the real benefits of the Food Banks program, etc. It can resolve the public's doubts about the circular economy with real examples of life-oriented issues or actual cases. The purpose is to increase the breadth and depth of future promotion.

3. ACKNOWLEDGEMENTS

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4. APPENDICES

Records of the 2022 Green Synergy Solution Events

Policy Dialogue:
https://drive.google.com/file/d/1rgcGknPM43JOyks4BnsM4RDFaEQElkHM/view?usp=sharing

Workshop I:
https://drive.google.com/file/d/1YP-Ah9a3DgNLJBn2ONJjuRO3xgyN-aCV/view?usp=sharing

Workshop II:
https://drive.google.com/file/d/1WyL0mAWtwXLPu_CoRHMjUcQ1xfkXmhiI/view?usp=sharing

On-site Technical Practice:
https://drive.google.com/file/d/1iZAjAVMGgwxxP_XA_cBHp2ulBASHpqQK/view?usp=sharing

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ANNEX I - AGENDA

2022 Green Synergy Solutions Events

September 15th │ Policy Dialogue InSky Hotel, Taichung, Chinese Taipei	
Time	**Session**
09:00 - 09:40	**Opening & Greeting**
09:40 - 10:15	**Session I** **Net Zero Policy in Viet Nam** Dr. DOAN TRINH TA National Institute for S&T Policy and Strategy Studies, Viet Nam **Establishing the Hydrogen Circular Economy in Indonesia** Prof. Dr. Eng. ENIYA LISTIANI DEWI National Research and Innovation Agency, Indonesia
Coffee Break	
10:30 - 11:15	**Session II** **Promoting Circular Economy on Touristic Islands: Where Is the Bottleneck?** Dr. PANATE MANOMAIVIBOOL Mae Fah Luang University, Thailand **Optimizing Bio-circular Economy for Rice-based Farming Communities** Dr. HAZEL BITENG ALFON Philippine Rice Research Institute, The Philippines **CMU BCG Demonstration Area: The First Step towards Carbon Neutrality** Dr. PRUK AGGARANGSI Chiang Mai University, Thailand
Coffee Break	
11:30 - 12:00	**Session III: Panel Discussion** **Bio-wastes to Green Hythane** Prof. Dr. CHUN-HSIUNG HUNG NCHU, Chinese Taipei **Bio-circular Economy** Prof. Dr. BING-CHWEN YANG NYCU, Chinese Taipei
Lunch Break	

September 15th │ Workshop I – Lectures InSky Hotel, Taichung, Chinese Taipei	
Time	**Session**
13:00 - 13:15	**Opening**
13:15 - 14:00	**Session I** **Biogas Technology Development: Case Study from Indonesia** Prof. Dr. UDIN HASANUDIN University of Lampung, Indonesia **Sustainable Technology in Oil Palm Waste Management** Dr. PEER MOHAMED National University of Malaysia, Malaysia **The Development of Ocean Hydrogen in Viet Nam: From the Approach of an Eco-friendly Electrochemical Method and Suitable Support Policies** Dr. THIEN KHANH TRAN Van Lang University, Viet Nam
Coffee Break	
14:15 - 15:15	**Session II** **Edge/cloud-aided Energy Management Agent for Cooperative Energy Management and Demand Response Services** Prof. Dr. JIN-SEEK CHOI Hanyang University, Republic of Korea **Climate Action as a Catalyst for Improved Socio-economic Development Outcomes** Dr. MEGAN ARGYRIOU ClimateWorks Centre, Monash Sustainable Development Institute, Australia **Smart Islands** Dr. FRANCESCO PETRACCHINI Institute of Atmospheric Pollution Research, National Research Council, Italy **Lignocellulosic Biorefinery: Progress towards Circular Economy** Prof. Dr. GOPALAKRISHNAN KUMAR Yonsei University, Republic of Korea
Coffee Break	
15:30 - 16:00	**Session III: Panel Discussion**

September 16th │ Workshop II – Young Entrepreneurs Training Program InSky Hotel, Taichung, Chinese Taipei	
Time	**Session**
09:00 - 09:30	**Opening & Greeting**
Final Pitch: 10 minutes presentation and 20 minutes Q&A	
09:30 - 11:30	**Session I** **Affordable and Biodegradable Sanitary Pad** TEAM Lima Kaki National University of Malaysia, Malaysia **From Shrimp Shells to Nano-chitin** TEAM ChiTom Hanoi University of Science and Technology, Viet Nam **From Agricultural Waste Rice Straw to Value Added Facial Masks** TEAM Giao Wao Deyimia Feng Chia University, Chinese Taipei **Integrated Biogas Power Plant in Educational Farm for Cacao and Deer** TEAM Biogasverse Bandung Institute of Technology, Indonesia
Lunch Break	
12:30 - 14:00	**Session II** **Chitin Production from Shrimp By-products Using Microbiological Method** TEAM DTH Ho Chi Minh University of Technology, Viet Nam **Riceing Gas** TEAM RICEing Gas Central Bicol State University of Agriculture, The Philippines **Eco-Boba** TEAM Bi Bi Dan China Medical University, Chinese Taipei
Coffee Break	
14:15 - 15:45	**Session III** **Bioenergy and Bioproducts Derived from Sugarcane Waste in Thailand** TEAM Holeless Donut Khon Kaen University, Thailand

	Bioelectrochemical system (BES): **An overlooked key to circular bio-economy and sustainability** TEAM FIVE UKM National University of Malaysia, Malaysia **Mobile Swimming Robot** TEAM Lomonosov_MSU Lomonosov Moscow State University, Russia
Coffee Break	
15:45 - 16:15	**Reviewers Meeting**
16:15 - 16:30	**APEC ACABT Steering Committee Meeting**
16:30 - 17:00	**Award Ceremony**

September 17th │ On-site Technical Practice Green Birth Farm, Nantou, Chinese Taipei	
09:00-17:00	**HyMeTek Demo-site Visiting (Only for physical participants)**

ANNEX II - POLICY FRAMEWORK REVIEW

Green Synergy Solutions for Sustainable Community on Agriculture Residue-Based Energy and Circular Economy

ABSTRACT

This proposal aims to promote an eco-community using considerable bio-wastes, such as corn straw, rice straw, sugar bagasse, and palm oil residue. The bio-wastes are rich in carbon, nitrogen, and phosphorus nutrients that can produce green hythane and bio-fertilizer by synergetic bio-refinery processes for circular economies in the APEC region. The improper treatment process of bio-waste could cause heavy impacts on environments across APEC economies. This project provides a platform to create and share innovative and affordable technologies for minimizing the environmental impact and meeting the priorities of increasing inclusion and sustainability for recovery in APEC 2021. This policy framework review includes two issues: the first is “Bio-wastes to Green Hythane,” and the second is “Bio-circular Economy.”

A. BIO-WASTES TO GREEN HYTHANE

BACKGROUND

Bio-wastes from small-scale agricultural operations hardly cause any environmental concern as it could easily convert back into nature, serving as fuel or fertilizer. However, as the farming approach becomes concentrated on a large scale with advanced technique support, the fast-growing amount of bio-waste production becomes a main worldwide concern. Improper treatment processes on bio-waste could cause air, water, and soil pollution; and greenhouse gas emissions across APEC economies. Therefore, strategies for their amendment are needed to reduce the environmental burden.

In recent decades, hydrogen or methane production from organic-rich bio-wastes via anaerobic digestion has emerged as a well-accepted practical approach compared to other biological means. Since these wastes are also rich in nitrogen and phosphorus nutrients, residuals of anaerobic digestion could further serve as bio-fertilizers to fulfill the circular economy in the APEC region. The 21-member economies of APEC spread with distinct climates, as well as agriculture patterns. These differences affect agricultural production because it depends on specific climate conditions. Therefore, the characteristic of bio-wastes produced differs significantly among APEC members. Converting bio-waste to green biohythane must take this into account.

FOCAL POINTS

a. Current regulations of the circular economy related to agro-waste management

Ellen MacArthur Foundation defines circular economy thus: “A circular economy is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles” [**1**]. Later the same foundation further states that the circular economy is on the basis of three principles, driven by design: (1) Eliminate waste and pollution. (2) Circulate products and materials (at their highest value), and (3) Regenerate nature [**2**]. These three principles could be well-described by circular agriculture. Livestock wastes are collected for anaerobic digestion to reduce waste concentration and pollution, followed by land application of digested residuals as organic fertilizers to produce new agricultural products. Biogas, such as hydrogen and methane, fuels the generator to provide electricity for farm usage, and then a complete cycle occurs. Therefore, regulations on carbon footprint and agro-waste management should be a part of the policy recommendations.

Chinese Taipei

To cultivate economic development and industrial transformation, the government proposed the “5+2 innovative industries” as the core of its industrial policy. The “5+2” means five industries and two transformation strategies: The five industries include Asian Silicon Valley, the Biomedical industry, Green energy technology, Smart machines, the Domestic defense industry, and the two transformation strategies, including Circular economy and New agriculture [3]. “Plus 2” is not industry-specific but aims to help every industry to incorporate resource recycling into its strategy and model. The circular economy system allows us to preserve resources and products at a higher value and repeatedly circulate. New agricultural technology uses bio-refinery and cascading to produce t raw materials that industries need.

Under this policy framework, the Council of Agriculture (COA) and the Environmental Protection Agency (EPA) stepped forward to encounter carbon footprint and agro-waste management. In 2019, COA established a project-based Office of Climate Change Adjustment and Net-Zero Emissions. It also set four working targets, such as Carbon Emission Reduction (Low carbon production mode, precise fertilizer application, and reduction of ocean fishing scale), Carbon Sink Increase (Increasing forest density and bamboo planting), Carbon Circulation (Anaerobic digestion residual application), and Green Energy Trend (Producing own electricity and treat own waste).

At the same time, the EPA set relevant regulations to enforce renewable energy developments, with an emphasis on establishing anaerobic digestion plants. This livestock wastewater used to be in the discharge to the nearby river without proper treatment. By forcing carbon emissions to be returned to farmland, it required strict anaerobic digestion requirements that emphasize anaerobic hydraulic retention time to enforce biodegradation. Feeding materials include kitchen waste, agricultural/forestry waste, and livestock waste. After purification, biogas goes to electricity generation while fermentation residuals return to farmland as fertilizer. EPA also ensured that no carbon was released into the atmosphere by open-field incineration to reduce air pollution. High-tech equipment, such as drones and infrared telescopes, were applied with positive results. Not to mention that these plant residuals could be in shipments to anaerobic digestion for more gas production.

Viet Nam

With the proposal to combine further economic growth with higher environmental sustainability and better carbon footprint management, the ”Viet Nam Green Growth Strategy (VGGS)” obtained approval in 2012. The VGGS aims to accelerate the process of economic restructuring to use natural resources efficiently, reduce greenhouse gas emissions through research and application of modern technologies, develop infrastructure to improve the entire efficiency of the economy, cope with climate change, contribute to poverty reduction, and sustainably drive economic growth [**4**].

The VGGS is an effort to synthesize green action plans of main sectors and society to (1) promote “green production” via more efficient use of resources and new technologies, which aims to facilitate sustainable production and create new green businesses; (2) reduce the intensity of greenhouse gas emissions by 8-10 percent compared to the 2010 level, reduce energy consumption per unit of GDP by 1-1.5 percent per year, and reduce greenhouse gas emissions from energy activities by 10 percent to 20 percent; and (3) stimulate green lifestyles and promote sustainable consumption [**4**].

Agro-waste management for ecological agriculture and sustainable development has become an issue of concern for the Viet Nam government. The government and other functional organizations are paying greater attention to the means for recycling agricultural waste and residual. The development of intensified crop production systems and high-yielding modern varieties, which address food security issues, increased the number of crop residues (rice straw, rice husk, coffee husk, and other agricultural by-products) left in the field after harvest. Accompanying this development have been wastes from the irrational application of intensive farming methods and the abuse of chemicals used in cultivation, remarkably affecting rural environments. On the other hand, livestock production in Viet Nam is growing and industrializing and spatially concentrating often in troublesome proximity to densely populated areas even while remaining smallholder-dominated. Wastes from livestock activities include solid wastes such as manure and organic materials in the slaughterhouse; wastewater such as urine; cage wash water; wastewater from animals bathing and maintaining sanitation in slaughterhouses; air pollutants; and odors [**4**].

b. The modification and suggestions on carbon emissions management will allow the bio-wastes materials to become sustainable resources

In times of depleting resources, there is a quest for carbon emission management solutions in a circular economy. Bio-wastes, such as agricultural residuals, livestock manures, and kitchen waste, attract increasing global attention to their conversion to sustainable resources and simultaneously reduce greenhouse gas emissions for carbon neutrality. Gate fees need to be low enough to be more financially attractive than sending bio-waste to landfill to encourage the use of recycling and resource recovery facilities. Diverting organic material through composting, recycling, or anaerobic digestion facilities could reduce carbon emissions significantly. These bio-waste circular solutions also provide a way to return valuable nutrients such as nitrogen, potassium, and phosphorous to soil and aid plant growth. The microorganisms in compost promote soil microbial health and diversity and boost the storage of organic soil carbon. It is a win-win situation for carbon emission reduction and sustainable resource production.

<u>Chinese Taipei</u>

On March 30, 2022, the NDC, the policy-planning body, announced the “2050 Net Zero Emission Roadmap.” This roadmap proposes four transitions: Energy transition, Industrial transition, Life transition, and Social transition, as well as the two governance foundations. “Technology research and development” and “Climate legal system”, supplemented by 12 key strategies. “Hydrogen” and “Resource Circulation and Zero Waste” are among the strategies related to bio-waste to green hythane. The government plans to invest approximately US$31.5 billion in carrying out the plan from 2022-2030 [**3**]. According to the framework, the authority will modify its carbon emission management plan by shifting to a low-carbon economy by utilizing proven mature green energy and carbon-reducing technologies. Over the long term, the authority will target Net-Zero Emissions by investing in hydrogen energy, the circular economy, and carbon capture utilization and storage (CCUS) technologies and solutions.

The Bureau of Energy and MOEA gave an impetus to the “Biogas Power Generation System Subsidy Program” and approved Pintung and Changhua county government subsidy applications in 2013. The installation capacity of all biogas power generators has reached 390 kW. These biogas power generators are estimated to generate over 2.52 million kWh per year, reduce costs up to 7.08 million NTD, and reduce 1,350 tons of CO_2 emission equal to the carbon sequestration capability of 55 thousand trees [**5**].

At the same time, the MOEA strives to promote biogas and power generation integrated systems for diverse residues or sewage treatment plants in the economy. This year (2013), Pingtung County’s “Biogas Power Generation System Project for Linluo Township Central Farm” and Changhua County’s “Sewage Treatment Plant and Biogas Power Generation System Project for Hanbao Farm” obtained approval. In the future, the central government will keep cooperating with local governments to promote the application of bio-power generation and accelerate the achievement of renewable power generation. Authority will continuously promote biogas utilization from agro-waste, animal husbandry waste, and sewage treatment plants based on the Renewable Energy Development Act. In addition to substituting fossil energies, biogas power generation can reduce power costs and mitigate global warming. In 2030, the installation capacity of biogas power generation will achieve 31 MW which is three times larger than the current status [**5**].

<u>Viet Nam</u>

As part of the VGGS, Viet Nam has established greenhouse gas emission reduction and related targets based on studies of sectors with high emissions, such as the energy, forestry, and agriculture sectors. Viet Nam undertook a Marginal Abatement Cost Curve (MACC) analysis on the key sectors. They showed significant win-win options among the energy and agriculture sectors and cost-effective opportunities in the forestry sector. The study underlined that with appropriate levels of investment. Viet Nam's target, greenhouse gas emission reduction, can be achieved while maintaining a high economic growth level [**4**].

Agro-waste management for ecological agriculture and sustainable development has become an issue of concern for the Viet Nam government. The agricultural sector plays an essential role in Viet Nam's economy. Together with the trend of agricultural intensification that aimed at responding to the surge in demand, the number of agro-wastes and residues from crop production and livestock increased rapidly. Viet Nam produces almost 100 million tons of crop residues/agricultural by-products and generates 84 million tons of livestock waste annually. Take rice as an example. According to survey results from the Low Carbon Agricultural Support Project, Vietnamese farmers have several kinds of rice residue management in the field, which include burning residue in the field, incorporating it into the field, and removing it from the field, either for feeding cattle herds or mulching for succeeding crops. The survey data also showed that more than 50% of the farmers burned or/and incorporated rice straws after harvesting. The open-field burning of rice straw is still a problem in intensive rice-based cropping systems in Viet Nam [**4**]. The livestock sector in Viet Nam also plays an essential role in agriculture. It accounts for 35 % of agriculture's gross value added. Semi-industrial and industrial livestock production accounted for 64.2 % of the subsector's total output; smallholder and small-scale production accounted for the remainder. Intensification of livestock farming from big farms often produces wastes much more than their capacity to recycle for use as fertilizers and biogas. As of 2019, Viet Nam's livestock sector generated an estimated 86.92 million tons, higher than 2.62 million tons compared to 2018. The total amount of solid animal waste generated in the economy weighed around 87 million tons in 2019. Pigs account for 20%, poultry 39 %, cows 23 %t, and buffalos 14 %. From geographical distribution, the region that generates the most livestock waste is the Red River Delta, followed by the Southeast and the Mekong River Delta. Pig farming mainly locates in lowlands and populated areas and causes severe pollution compared to other animal farming species [**4**].

In 2019, around 68% of the total number of livestock farms had applied measures to treat animal wastes (30.2% treated by biogas systems; 25.6% separated solid waste to sell out; 6.4% used bio-mat bedding; 1.9% used for composting; 3.9% applied other treatment methods). 32% had not applied any treatment before discharging into the environment [**4**]. There is a gap between the potential of agricultural waste and residual recycling. Modifying carbon emission/ bio-waste management is in strong need for the Viet Nam government and functional organizations, especially in collecting these agro-wastes to produce energy.

c. Comparison of the carbon and resource supply management regulations to the biomass promotional objective, and its further limitations on the green hythane promotion

Any economy needs diverse energy resource supply and alternatives. Especially for most APEC member economies, the energy's diversity is so finite that they need additional energy imports. Regulation optimizations on carbon and resource supply to promote biomass conversion to bioenergy must be in consideration.

<u>Chinese Taipei</u>

To reduce carbon emissions, the government set goals of gradually abandoning nuclear power plants by 2025, proposing an energy composition plan by adopting 50% from natural gas, 30% from coal, and 20% from renewable energy, respectively. Within the twenty percent of renewable energy source, solar and wind power each takes the lead when weather conditions are suitable. For example, when the sunshine peaked in the sky on 2 September 2019, solar photovoltaic generation broke past the threshold of 2 GW for the first time in the economy. At 11:40 p.m. on the same day, solar power generation reached 2.09 GW, accounting for 5.89% of the power supply. It surpassed the economy’s largest nuclear power plant, the second power plant (1.97 GW) or the third power plant (1.9 GW) [**6**]. In 2018, only 5% of the electricity generated in the economy came from renewable energy. In 2022 (Jan to May), renewable energy production reached 8.06% (3.05% from solar energy and 1.2% from wind power) [**7**]. It showed that despite the solar and wind power, the government is still facing challenges of finding a steady energy alternative to make up the 20% renewable energy goal by 2025. Thus, renewable energy production from biohydrogen and biomethane should come to the rescue.

There has been a limitation on promoting biohydrogen and biomethane production in the economy. It is the lack of horizontal connections among government agencies [**8**]. Under various regulations, the MOEA is responsible as an authority for keeping a safe and stable energy supply and promoting energy diversification and usage. However, converting biomass to energy includes using domestic/industrial wastes, livestock manures, kitchen wastes, and plant residues by the EPA and the COA instead of the Bureau of Industrial Development, MOEA. Thus, there should be cooperation among the agencies to promote biohydrogen and biomethane production. For example, the Bureau of Energy supports installing newly designed anaerobic digestion systems built for livestock manures, sewage, and domestic/industrial wastes. The COA provides financial support to livestock farm owners willing to collect manures and install an anaerobic digestion system with an electricity generator. The EPA collaborates on biomass and kitchen waste fermentation project on the residue and slurries land applications.

Viet Nam

There are considerable agro-wastes from both planting and livestock discharged into the environment, which needs better carbon and resource supply management. The policies should reform to help various farms comply with existing environmental standards. Nowadays, livestock waste management in smallholder farms is not enforced or monitored. From the producers' perspective, waste treatment requires onerous investments in infrastructure, which small farmers can hardly afford. A lack of awareness about the importance of waste treatment also factors into farm-level decisions. However, the authority does not enforce the waste management regulations uniformly and systematically, especially among smallholder farms. The result is that farmers tend to avoid treating animal wastes when and where possible. Therefore, the production of green hythane is limited. Over the past few years, the government has initiated livestock projects that financially support smallholder farmers. The projects aim to help them handle livestock wastes, notably through the biogas digesters and composting facility constructions [**9**].

While the biogas digesters construction is viable for some small-scale pig farms, it is not yet an attractive measure for large-scale farms in light of the large volumes of animal waste because of the excessive volumes of biogas and biogas slurries. Only a low proportion of gasses produced by medium- and large-scale farms is for cooking. Most of the remaining excessive gasses are heading into the environment. Some farms try to install generators operated by gas to produce electricity. However, it is not yet economically viable due to the following reasons:

1. The low electricity prices maintained by the state;
2. The technical complexity and expense of constructing medium-/large-scale biogas digesters;
3. The limitations of gas purification technology;
4. The high cost of high-quality generators.

The release of gasses and slurries from biogas digesters remains a big problem in medium- and large-scale pig farms. Local governments should pay greater attention to environmental enforcement for large-scale and smallholder farms from the registration stage, strictly monitor waste handling and treatments during operation and apply appropriate penalties for violators [**9**]. Law enforcement, which indeed works, is what the economy has been doing over the past five years.

B. BIO-CIRCULAR ECONOMY

BACKGROUND

Because of the deterioration of the global environment, the world reached a consensus on carbon neutrality. Most economies have also taken corresponding measures to reduce carbon emissions and slow down the continuous deterioration of the global environment. Among these measures, in addition to increasing the supply of carbon-free energy, such as renewable energy from the supply side, it is also required to reduce energy consumption from the demand side. However, recycling and reusing limited resources from the Earth is relatively essential. Appropriately managing the Earth's resources can help to mitigate and reduce the environmental deterioration caused by overconsumption. Especially for the recycling and reusing of biological resources can be greatly helpful for our environment due to the advantage of trouble-free conversion by the existing technology. Besides, it also can reduce resource waste for long-term waste treatment. Thus, it means all these efforts can protect our environment.

Agriculture accounts considerably for economic activities in the 21 APEC member economies. Most economies are undergoing comparatively rapid economic development, and the demand and expenditure on various resources are relatively high. They must implement technologies for recycling biological resources in different stages to maintain our environment while pushing forward the economic development in the APEC Region. It will lead to a need for concept implementation of the bio-circular economy. It means that bio-wastes can convert into carbon-free energy or products with higher economic value through a technological introduction.

The European Union announced the Circular Economy Strategy (EU Action Plan for the Circular Economy) in 2015. It covers widely from industry to biology and prioritizes promoting bio-based products, biomass, and food waste for recycling and reusing. However, biological products are decomposable and indecomposable materials. Therefore, it is necessary to analyze the recycling and reusing of different materials simultaneously. Therefore, it is essential to cooperate with biological and industrial cycles, best utilizing the various biological resources. The promoters will develop and facilitate the “resource platform” for different types of bio-wastes based on the “Agriculture Circular” [**10**].

According to the EMF report in 2015, the essential green energy technologies of the bio-circular system include the following items: biomimicry, composting, algae, and biofactories (microbial waste treatment plants), biorefinery (which can convert abundant bio-wastes by refining to increase their values), anaerobic digestion, and biodegradable food packaging [**11**]. Even during the threat of the COVID-19 epidemic, people still need to maintain and even strengthen the sustainable development of the circular economy. One of the focus points is to put on the biological industry and biological recycling due to the value chain of the bioproducts. It is also an example of utilizing sunshine, air, water, and soil for bio-related materials or products in the life cycle. It is highly recyclable and has a high proportion of decomposable characteristics. Thus, it is capable of replacing general and indecomposable wastes and pollutants. In other words, there is no additional carbon emission in the life cycle, which could be deemed consistent with the future need to meet Net-Zero Emissions by 2050. Concerning environmental maintenance, the bio-circular economy has the potential for environmentally sustainable development to replace the current business model that traditionally only considers CP for evaluation [**12**].

Let’s take Chinese Taipei as an example. In response to the trend and policy goals of Net-Zero Emissions by 2050, the authority planned for four transformations: Energy transformation, Industry transformation, Life transformation, and Social transformation. Besides, there were two other government approaches, i.e., technology research and development and climate legal system. To achieve Net-Zero Emissions by 2050, the government announced twelve key strategies. One of them was “Resource Recycling and Zero Waste” An estimation had it that, by 2030, there will be a 21.7 billion NTD investment in the “Resource recycling and zero waste” strategy to help achieve Net-Zero Emissions.

FOCAL POINTS

a. Reuse of waste food materials - how to reduce food crisis by making full use of food materials

An estimation indicates that at least one million tons of food waste in Chinese Taipei occur yearly. In North America, 40% of the food is wasted [**13**]. At the same time, some problems result from food shortages (such as hunger, famine, turmoil, etc.) in other economies. It even affects the smooth growth of children. Therefore, in addition to causing food shortages, the wastage of food materials has also resulted in many social problems.

The focus of future development and public education will be on the “upcycling” of the waste food or the regeneration, that is, the use of discarded waste food to regenerate new food. The “upcycling” of food waste reduces bio-related waste. It is a new way for food industries to deal with waste ingredients and creates new business opportunities. According to a report published by London Market Consultancy - Future Market Insights (FMI) in 2019, the estimated global market for leftover food is US$46.7 billion. The amount is increasing at a compound annual growth rate of 5%. [**14**].

“Upcycling” food allows the value of discarded bio-related ingredients to continue their value in another way. This new development also exhibited the creativity of the food industry in production and processing. It brought more valuable new products into the market and contributed to the sustainable development of the environment. That is, it is a business opportunity under the bio-circular economy.

b. Differences in the utilization of biomass energy and fossil energy - how to avoid the potential harm of biomass energy to the original fossil energy facilities

Using biomass energy converted from plants or other bio-materials, this natural cycle of plants or bio-materials can relatively reduce the carbon dioxide and other polluting gases, or greenhouse gases emitted by burning fossil fuels simultaneously. Thus, it is one of the options for us to face the target of Net-Zero Emissions by 2050. However, almost all the existing energy facilities are designed based on the characteristics of fossil energy. After mixing several percentages of bio-energy or replacing the bio-energy, there must be certain adjustments in the system or maintenance to function well. Taking the mixing of biodiesel, an excellent solvent, with original diesel from fossil fuel as an example, if the oil residue deposited in the existing pipeline dissolves out and blocks the filter or other oil circuit, it may cause problems in the operation of the original system.

Therefore, the focus on the efforts of future development and public education can be “how to make the characteristics of bio-energy match the characteristics of existing fossil energy as much as possible from the production process of bio-energy.” On the other hand, it is necessary to discuss the change in the long-term maintenance and operation methods for various energy facilities to avoid potential problems during the operation and reduce people's confidence and willingness to use bio-energy.

c. Impact of the bio-circular economy on people's livelihood - how to reduce people's doubts about recycling

For the circular economy and sustainable development of the environment, waste recycling has become a consensus to the public and a focused policy for the government. While the bio-circular economy somewhat causes controversy, such as “energy and food, which is more important for us?” Safety issues for waste food recycling and re-produce are also important. All these issues will bring ideas or viewpoints to different groups. Most of the time, it also causes disputes in our society along with bio-circular economy promotion.

Therefore, future development and public education can focus on issues related to people's lives, such as how to show the flow of waste food materials through information platforms, the role of incinerators in the cycle for the energy and environment, and the real benefit of the Food Banks program in Chinese Taipei, etc. It means that resolving the public's doubts about the bio-circular economy can be done through real examples of life-oriented issues or actual cases. The purpose is to increase the breadth and depth of future promotion.

C. POLICY DIALOGUE TOPICS AND RECOMMENDATIONS

BIO-WASTES TO GREEN HYTHANE

a. Hydrogen, methane, or mixed biogas

Anaerobic digestion of organic wastes has been well-studied. Two separated microorganism groups are for converting organics to hydrogen with VFAs (volatile fatty acids) and finalizing the reaction to produce methane. The two groups of functional microorganisms have distinct growth conditions, such as pH and retention time. Simple one-stage reactors from production to methane have worked throughout food industries and wastewater treatments. Hydrogen gas is greener energy than methane. Thus, the two sequencing reactors are either designed by separating the hydrogen and methane production stages or by stopping digestion after hydrogen production. The above has drawn attention to fulfill the different requirements.

Therefore, the authorities must implement the recommended policies of developing hydrogen, methane, or mixed biogas in each APEC member economy before they promote bio-waste digestion. It will significantly affect the process design and further requirements on gas-to-electricity production.

b. Maintaining the stable gas production by co-digestion with other organic wastes

Biogas production by only using agro-waste is not an ideal design. Crops' growth must follow seasonal requirements. There is an extremely high amount of produced crop waste after the harvesting season. In other words, there could be times when anaerobic digesters receive no crop waste-feeding material for biogas production.

There should be a policy for the co-digestion of crop waste and other organic waste collected stably over time. Livestock wastewater, such as swine and kitchen waste, are two possible and potential candidates for this purpose. Related policies must include waste transportation, odor control, and process design for co-digestion.

c. Carrot and stick

Open space crop waste incinerations have been a severe air pollution problem in many economies. The EPA in Chinese Taipei has applied new technologies, such as drone inspection and infrared sensing, and achieved significant case reduction. There should be strict policies and fines on banning crop waste incinerations, followed by acquiring the crop waste as feeding material for anaerobic digestion centers.

Another policy that should be in consideration is promoting the green electricity market. It can be achievable by either FIT (Feed-in Tariff) or Renewable Portfolio Standard (RPS) that stimulates marketing of biogas from bio-waste.

BIO-CIRCULAR ECONOMY

The planning of a bio-circular economy must begin at the source. Thus, there should be six main steps: Polyculture, Production Optimization, Full Use, Sales and Logistics, Separation/Collection, and Resource Recovery. Then develop each technology one by one according to these six steps. Of course, the basis is still the establishment and analysis of the database and then the development of the corresponding Practices/Strategies/Policies [**15**].

a. Collect biological breeding and planting databases from various economies to understand the balance and complementarity of reproductive substances in the APEC region.

b. Build a platform for the bio-circular economy exchange, covering the level of technological development, the list of manufacturers, etc., to facilitate sharing and matching of information among economies.

c. Carry out the carbon footprint analysis for various biological recycling, and set up a supporting system for carbon rights to jointly achieve low-carbon or carbon-free development in the APEC region.

d. Develop a preferential tariff mechanism for bio-recycling products to reduce trade barriers and expand the development potential for the bio-circular economy.

e. Due to the food culture in the APEC region, there are lots of wasted food materials. However, most economies are in the stage of economic takeoff and fast development, and the imbalance of regional development is also the norm. Thus, a concept similar to the Food Bank in Chinese Taipei worth considering for policymakers in APEC Economies. It can reduce the waste of food and take care of the lives of ordinary remote or underprivileged people and should be a focus of development and policy.

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