APEC STI Strategic Foresight
: Net Zero Emissions/Carbon Neutrality Report

APEC Policy Partnership for Science, Technology and Innovation

October 2024

Asia-Pacific Economic Cooperation

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Economic Cooperation

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Table of Contents

1. OVERVIEW

Due to the profound and enduring effects of the COVID-19 pandemic, as well as the notable shifts in global trends observed in recent years, it has become imperative for the Asia-Pacific Economic Cooperation (APEC) to reevaluate its priorities and flexibly adjust its plans to effectively tackle both anticipated transformations and unforeseen challenges. In light of these evolving circumstances, APEC could leverage *foresight* methodologies as a strategic approach to pinpoint emerging issues, navigate uncertainties, and devise viable strategic options. The primary objective of this initiative is to anticipate future challenges, uncertainties, crucial agendas, and transformative technologies through strategic foresight techniques.

To achieve this goal, a comprehensive approach encompassing surveys and workshops involving representatives from APEC member economies will be undertaken. These engagements will serve as platforms for gathering diverse perspectives, insights, and data points relevant to the evolving landscape.

Following the collection of data and insights, a validation process will be conducted by professionals within APEC. This phase will involve thorough analysis to discern patterns, trends, and potential implications of the identified issues and opportunities. Through this critical assessment, APEC will be better to formulate informed strategies and policies designed to navigate future challenges and capitalize on emerging opportunities.

By proactively engaging in strategic foresight and collective comments from diverse stakeholders, this project endeavors to enhance its resilience, adaptability, and effectiveness in addressing the evolving needs and complexities of the Asia-Pacific region. This proactive approach underscores APEC's commitment to fostering sustainable growth, prosperity, and cooperation among its member economies in an ever-changing global landscape.

Theme: Net zero Emissions/ Carbon Neutrality

This project has reviewed statistical data sets of all 21 member economies in the APEC from the year 1990 to the latest year. There are a total of 77 data indicators categorized into 9 main themes as shown in the table below.

Table 1: APEC theme and indicators for background research

Theme	Number of indicators	Source
Climate	13	World Resource Institute (Climate Watch)
Demography	4	United Nations (World Population Prospects)
Economic	11	World Bank (World Development Indicators)
Energy	16	IEA (Energy Statistics)
Environment	5	Food and Agriculture Organization
Institution	8	World Bank (CPIA Database)
Technology	4	United Nations Industrial Development Organization
Tourism	2	World Tourism Organization
Trade	14	APEC Statistics

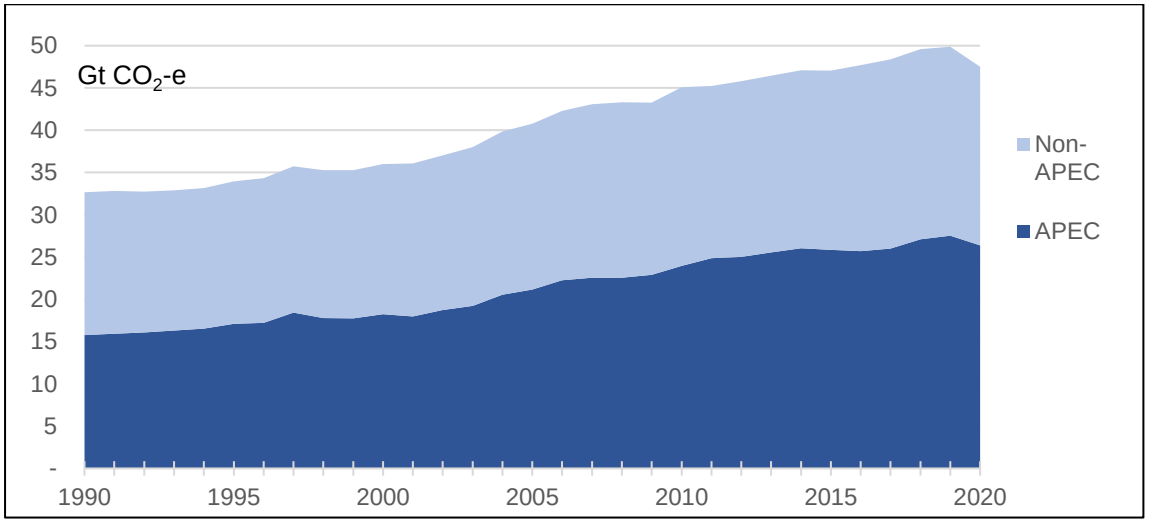
Note: Statistical indicator details are provided in Annex I

Key observations from the analysis of the data in the table are as follows:

- APEC emitted 26.4 billion tons of carbon dioxide equivalent (Gt CO_2-e) in 2020, accounting for 56 percent of global greenhouse gas emissions. Additionally, the emission rate of greenhouse gases from the APEC has been higher than that of

economies outside APEC over the past 30 years. The emission rate from the APEC increased by 67 percent (from 15.8Gt CO_2-e in 1990) compared to a 25 percent increase from non-Asia-Pacific economies, which rose from 16.9Gt CO_2-e in 1990 to 21.1Gt CO_2-e in 2020 as shown in Figure 1.

Figure 1: APEC and non-APEC greenhouse gas emissions during 1990-2020



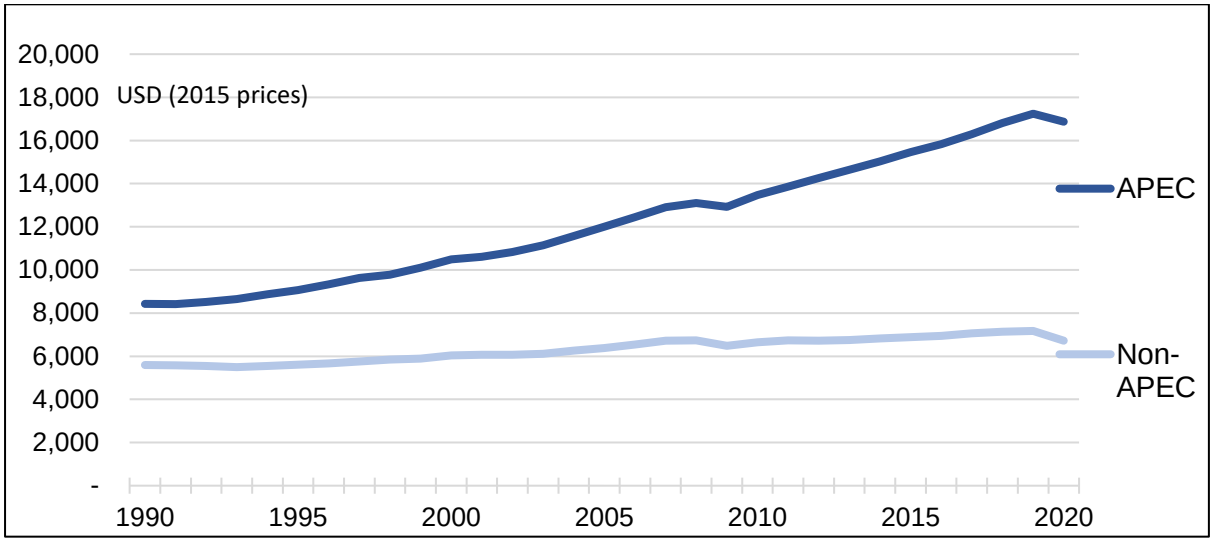
Source: World Resource Institute (Climate Watch)

- Figure 1 implies that more than 70 percent of the total increase in greenhouse gas emissions over the past 30 years has come from APEC economies. Although APEC emits greenhouse gases at a higher proportion and at a faster rate than economies outside the group, it can be inferred that APEC has greater potential for greenhouse gas reduction compared to non-APEC economies. This is because the APEC represents 60 percent of the global economy and only 37 percent of the global population. This means that policies and agreements within APEC could have a substantial impact on global carbon emissions.

- In 2020, the average income per capita in APEC was more than 2.5 times higher than that of economies outside the group. Furthermore, the average income of APEC has continued to grow steadily over the past 30 years, increasing by approximately 100 percent, from around USD8,500 per capita in 1990 to nearly USD17,000 in 2020. In comparison, the average income of economies outside APEC has only increased by 20 percent, from approximately USD5,600 per capita in 1990 to USD6,700 in 2020 as shown in Figure 2.

- The Paris Agreement, adopted in 2015, is a crucial international treaty aimed at curbing global warming by limiting temperature increases to well below 2°C above pre-industrial levels, with efforts to achieve 1.5°C. This agreement holds particular significance for APEC economies, as they face unique challenges due to their diverse economic structures and vulnerabilities to climate change impacts. As global leaders increasingly emphasize the urgency of limiting warming to 1.5°C, APEC economies must play a pivotal role in implementing measures to reduce greenhouse gas emissions and transition towards sustainable, low-carbon economies. This requires coordinated efforts and commitment from all APEC economies to peak emissions before 2025 and substantially reduce them by 2030, in alignment with the goals of the Paris Agreement.

Figure 2: APEC and non-APEC average income (per-capita GDP) during 1990-2020



The project was undertaken to address significant impacts of climate change in APEC region. Employing strategic foresight methodologies, the project aimed to identify future challenges, key agendas, and enabling technologies for achieving net zero emissions/ carbon neutrality in APEC. Delphi survey and foresight workshop involving participants from APEC economies were conducted to gather insights which were subsequently analyzed and verified by experts to propose key findings and recommendations for low-carbon strategies.

This project provided direct benefits to participants from APEC economies with a comprehensive understanding of foresight tools for strategic planning, while the long-term benefits are expected to emerge from collaborations among APEC economies to drive key recommendations proposed in the APEC Strategic Foresight report, designed to guide policymaking for sustainable growth in the Asia-Pacific region.

2. KEY STRATEGIES FOR NET ZERO EMISSIONS/ CARBON NEUTRALITY

The notion of “net zero emissions/ / carbon neutrality” gained prominence through the Paris Agreement, a significant accord established during the United Nations Climate Change Conference (COP21) to mitigate the effects of greenhouse gas emissions. While the Paris Agreement itself does not explicitly mention 'net zero,' governments are increasingly acknowledging the necessity of integrating net zero/ / carbon neutrality objectives into their Nationally Determined Contributions (NDCs), with some beginning to enact legislation to support such targets. However, it is well recognized that net zero emissions goal is individual voluntary contribution under UNFCCC.

According to the Intergovernmental Panel on Climate Change (IPCC) report in 2018, in order to adhere to the Paris Agreement's objective of limiting global warming to 1.5°C, there must be a reduction of approximately 45 percent in global human-caused carbon dioxide emissions from 2010 levels by 2030, ultimately reaching a state of 'net zero' around 2050. The IPCC asserts that any remaining emissions should be counterbalanced through the removal of CO_2 from the atmosphere. The 2021 Glasgow Climate Pact, established during the COP26 climate change conference, underscored the critical importance of achieving net-zero emissions by 2050 to effectively combat a temperature rise of 1.5°C.

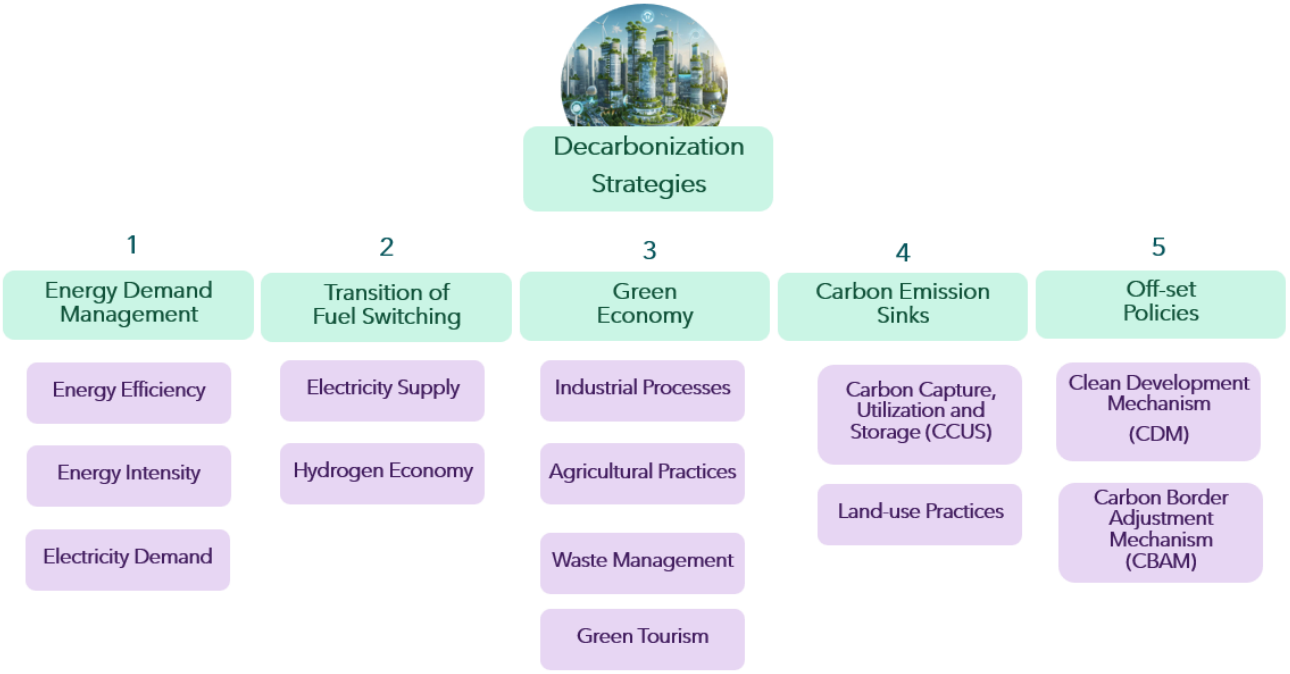
Key strategies for achieving net zero emissions / carbon neutrality include transitioning to renewable energy, improving energy efficiency, electrifying transportation, low-carbon industries, afforestation/reforestation, implementing carbon capture and storage, promoting circular economy practices, encouraging behavioral changes, enacting supportive policies, and fostering international cooperation. These strategies, discerned via a comprehensive literature review, are imperative to be executed concurrently for the successful mitigation of climate change. They have been deliberated across various stages over the past decades.

Given the gravity of these warnings and the escalating concerns surrounding global warming, extensive literature reviews have been conducted to explore effective strategies for achieving net-zero emissions/ carbon neutrality. Through examination and analysis, 5 key strategies are identified in this project:

1) **Energy demand management**
   This involves implementing measures to reduce overall energy consumption through efficiency improvements, behavioral changes, and innovative technologies.
   - *Energy Efficiency*
   - *Energy Intensity*
   - *Electricity Demand*
2) **Transition of fuel switching**
   Shifting away from fossil fuels towards renewable energy sources such as solar, wind, and hydroelectric power can significantly decrease greenhouse gas emissions.
   - *Electricity Supply*
   - *Hydrogen Economy*
3) **Green economy**
   Promoting sustainable practices across various sectors, including agriculture, transportation, industry, and tourism, can lead to economic growth while reducing environmental impact.
   - *Industrial Processes*
   - *Agricultural Practices*
   - *Waste Management*

4) **Carbon emission sinks**
Investing in artificial storages capable of absorbing and storing carbon dioxide and enhancing natural carbon sinks such as reforestation, can effectively remove carbon dioxide from the atmosphere.
    - *Carbon Capture Utilization and Storage*
    - *Land-use Practices*
5) **Offset policies**
Establishing mechanisms for carbon off-setting, such as carbon pricing or cap-and-trade systems, can incentivize emission reductions and encourage investment in carbon-neutral projects.
    - *Clean Development Mechanisms*
    - *Carbon Boarder Adjustment Mechanisms*

Figure 4: Decarbonization strategies framework



3. METHODOLOGY

The methodology employed in this project encompasses a multi-faceted approach aimed at comprehensive understanding and addressing future challenges and opportunities associated with key strategies for achieving net zero emissions/ carbon neutrality.

1) **Literature Review:** A thorough literature review was conducted to provide insights into the current status, trends, and emerging issues related to net zero emissions/ carbon neutrality. This involved scrutinizing academic papers, reports, and other scholarly sources to gain a comprehensive understanding of the subject matter and identify key areas for further investigation.
2) **Delphi Survey:** The Delphi survey methodology was used to collect insights and opinions from a panel of experts on net zero emission/ carbon neutrality strategies and their feasibility. This iterative process involved multiple rounds of questionnaires, enabling experts to anonymously provide feedback, refine their responses, and build consensus on critical issues.
3) **Foresight Workshop:** Foresight workshop was conducted using techniques such as the “Future Triangle” and “World Café” to engage stakeholders and explore potential future related to net zero emissions/ carbon neutrality. The Future Triangle methodology facilitated the exploration of three key dimensions: push, weight, and pull, helping participants envision potential pathways towards achieving net-zero emissions. Meanwhile, the World Café provided a collaborative environment for stakeholders to share insights, exchange ideas, and co-create strategies for addressing challenges and seizing opportunities in the transition to a low-carbon economy.

By integrating these methodologies, the project aimed to leverage diverse perspectives, expert knowledge, and foresight tools to inform the development of actionable recommendations for policymakers, stakeholders, and other relevant entities seeking to accelerate progress towards net-zero emissions/ carbon neutrality.

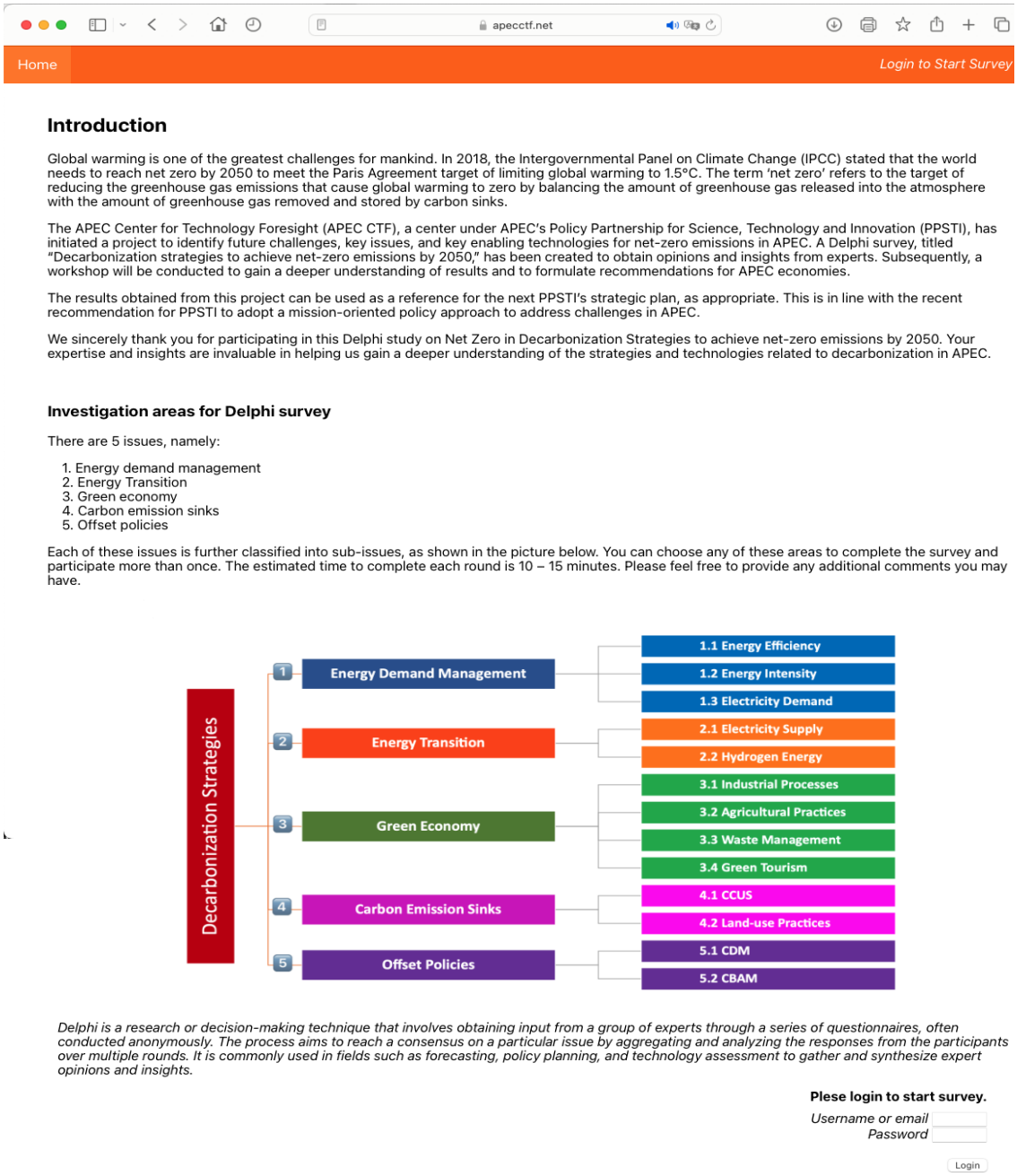
a. Delphi Survey

The Delphi survey plan involves a structured, iterative process to gather expert insights on specific topics. It begins with choosing a facilitator to oversee the survey. Experts are then selected based on their relevance, experience, and knowledge. The core of the survey is the Delphi statement which is a set of clear and precise questions. These questions are sent to the experts in multiple rounds, with each round's questions refined based on the previous responses. Finally, the collected findings are analyzed to inform planning for future risks and opportunities, leveraging the consensus or diverse perspectives gained through the survey.

Table 2: Summary of Delphi online survey processes

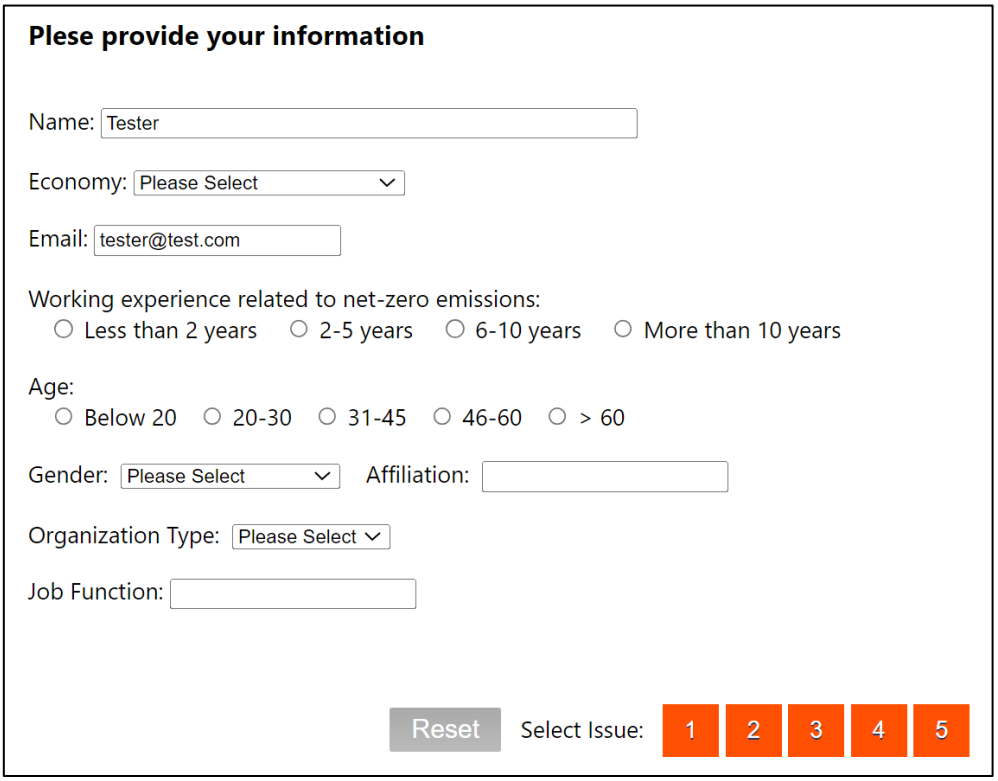
Stages	Activities	Time Estimate	Outputs
I.**Preparation**	• Setting research goals and framework • Initial input for selected topics • Formulation of Delphi statement and question refinement • Pre-test with research team and/or external experts	4 – 8 weeks	• Delphi Questionnaires
II.**Conduction**	• Selection of software tool and technical experts • Online survey pre-test • List of selected expert panel and invitation • Survey conduction for first and second rounds • Collection of experts' opinions and data	4 – 8 weeks	• Delphi Online Survey • Responses and Feedback
III.**Analysis**	• Data analysis and interpretation • Identification of consensus	4 weeks	• Expert opinions analysis including key insights and recommendations

Figure 5: Delphi online survey's webpage – First page



The Delphi online survey was sent to experts across APEC economies and conducted over two rounds (Figure 5). Responses were received from 16 of the 21 APEC economies, namely Brunei Darussalam; Chile; People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; Papua New Guinea; Peru; The Philippines; Russia; Chinese Taipei; Thailand; the United States; and Viet Nam. In terms of gender, 25% of respondents were female, 62% male, and 13% unspecified. Age distribution was as follows: 2% were between 20-30 years, 40% were 31-45, 29% were 46-60, 16% were over 60, and 13% unspecified. By experience: 14% had less than 2 years, 22% had 2-3 years, 20% had 6-10 years, 31% had more than 10 years, and 13% unspecified. The sectors of the respondents included 31% from government, 2% from the private sector, 40% from education, 14% from NGOs, and 13% unspecified.

Figure 6: Delphi online survey's webpage – Information page



Examples of the Delphi Online Survey's webpage are also shown in Figures 7 to 9. The list of the Delphi Online Survey's questions is provided in Annex II.

Figure 7: Delphi online survey's webpage – Questionnaires (Example)

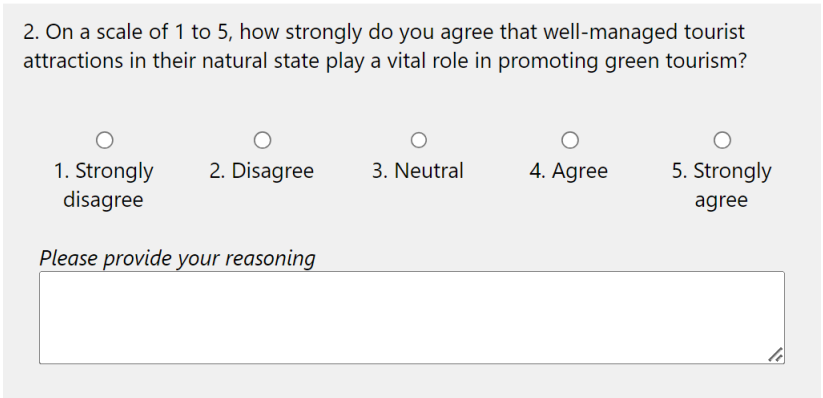


Figure 8. Delphi Online Survey's Webpage – Answers (Example)

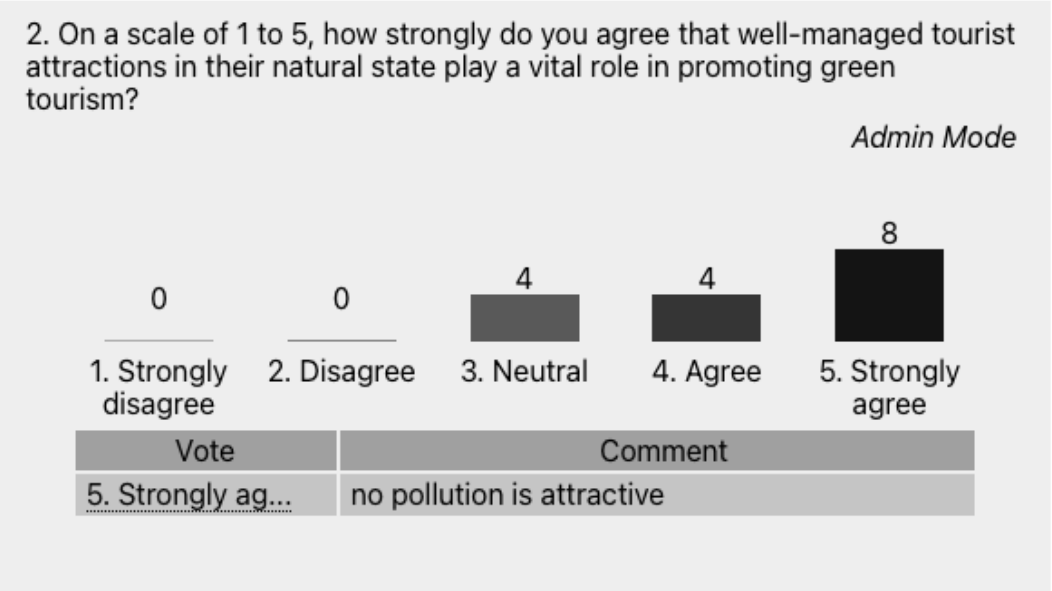
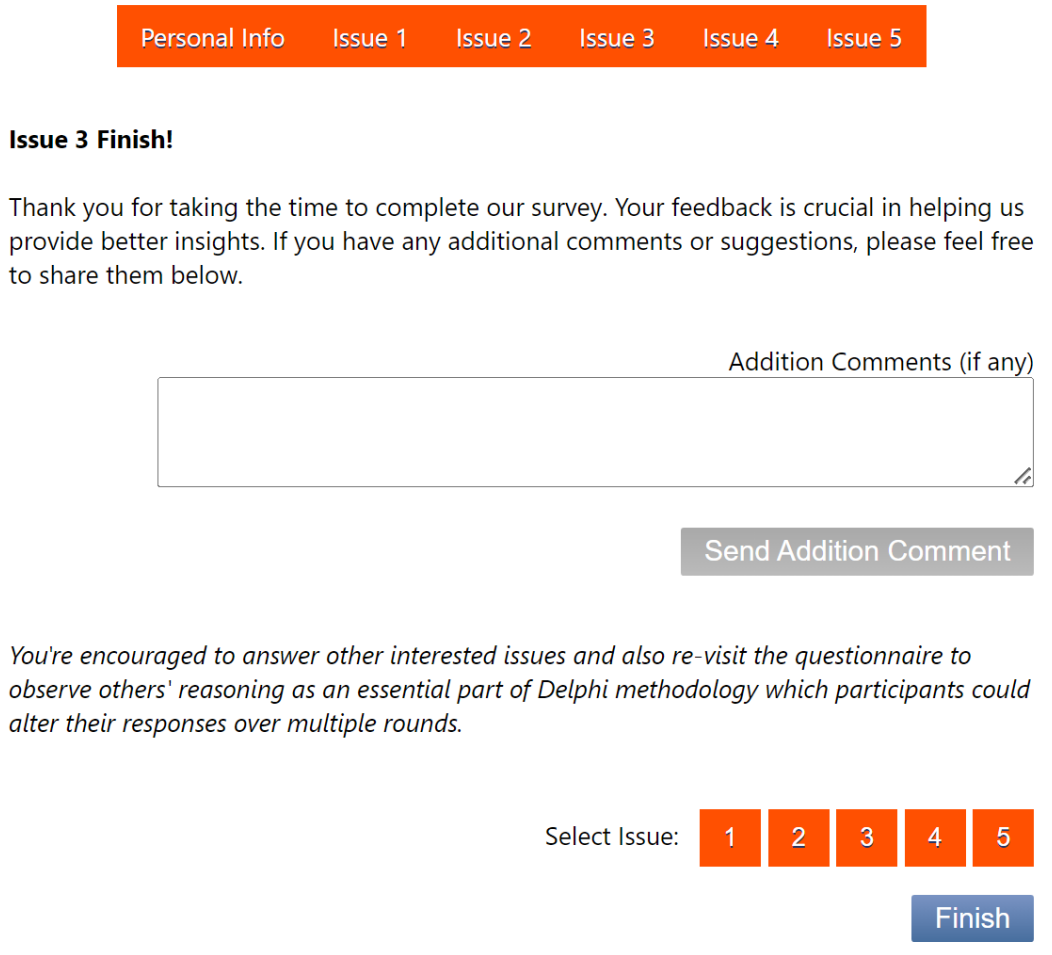


Figure 9. Delphi Online Survey's Webpage – Last page

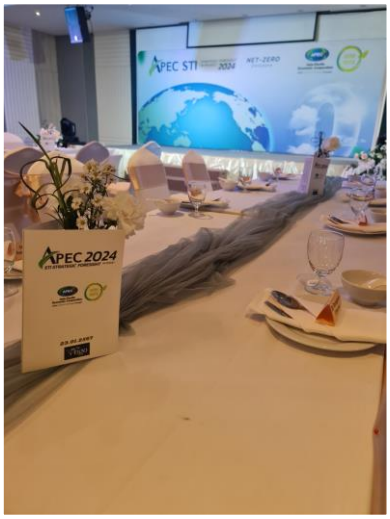


b. Foresight Workshop

The foresight workshop event was funded by the NXPO, underscoring its significance in advancing research and innovation. The event was honored to be opened by Dr. Kitipong Promwong, NXPO President and Executive Advisor of APEC Center for Technology Foresight (APEC CTF), further highlighting its importance and commitment to fostering collaboration and progress in the field.

The foresight workshop event 'APEC STI Strategic Foresight Workshop 2024: Net-zero Emissions' held over three days during 23 – 25 January 2024 in Phuket, Thailand, proved to be a highly enriching and collaborative experience. With a total of three sessions attended by over 48 participants representing 9 economies. The event facilitated in-depth discussions and provided valuable insights into strategic issues concerning the future achievement of net-zero emissions/ carbon neutrality in APEC. The event has been declared a carbon-neutral event. It has offset carbon credits equivalent to 21 tons of carbon dioxide emissions from the “Dan-chang Bioenergy Project” endorsed by Thailand Greenhouse Gas Management Organization (TGO).

Session 1: Setting the stage by example Commenced with a warm welcome dinner and the talk given by Dr. Siwarit Pongsakornrungsilp, Vice president Walailak University and Head of Krabi Model project. With the topic titled "Carbon Neutral Tourism in Thailand: The Case of Krabi Province," the event's focus aligned seamlessly with Thailand's pioneering efforts in pilot model tourism, particularly emphasizing carbon neutrality and the integration of local entrepreneurs. Setting the tone for productive exchanges about the significance of the event and its alignment with Thailand's pioneering efforts in pilot model tourism. This introductory session laid a strong foundation for the subsequent discussions and activities.



The case study of Krabi Province in Thailand exemplifies a significant shift towards carbon-neutral tourism within a globally renowned destination. Through proactive measures such as developing tailored tourism strategies, adapting to market structure changes, establishing a model spa town, and promoting green tourism initiatives, Krabi has positioned itself as a pioneer in sustainable tourism. Embracing digital platforms and focusing on high-value tourism experiences further underscore its commitment to environmental stewardship and economic viability. These efforts have not only shaped the Government's Annual Work Plan and the 5-year Krabi tourism plan but have also paved the way for the province's successful transition towards carbon-neutral tourism, marking a pivotal milestone in the global tourism industry's sustainability journey.

Session 2: Identifying key issues and collaborations Focused on foresight methodologies, notably utilized the Future Triangle framework to identify strategic issues and collaboration for achieving net-zero emissions/ carbon neutrality in APEC. Participants engaged in thought-provoking exercises aimed at exploring various scenarios and potential outcomes, thus enhancing their understanding of future challenges and opportunities

The workshop aimed to foster in-depth discussions by aligning Delphi survey findings, engaging experts to provide insights, and clarifying responses. Participants were divided into parallel rooms to effectively address sub-group issues. Recommendations sought input on strategic issues, challenges, opportunities, and collaboration feasibility. The foresight tool, Future Triangle, was utilized in each room to analyze the Push, Pull, and Weight of topics, facilitating comprehensive discussions.

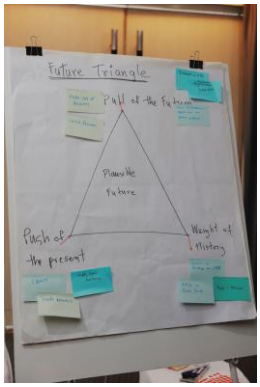
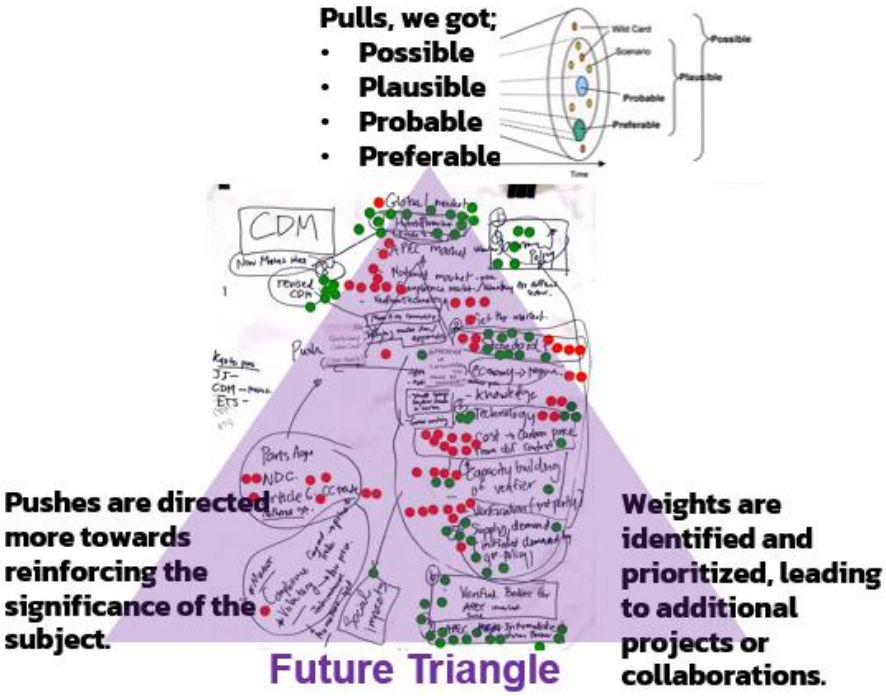


Figure 10. Example of results using future triangle tool



Future triangles provide us with an insight into the future vision of various topics. For instance, in the context of the clean development mechanism, it becomes evident that a strong driver of climate change is the push for this topic, reflecting global concerns to decrease greenhouse gas emissions. Additionally, initiatives such as Article 6 from the Paris Agreement allow for the trading of carbon, contributing to this push. On the other hand, the pull aspect represents the vision we must collectively pursue, emphasizing the need for market mechanisms to propel APEC collaboration forward and ensure stability. However, challenges arise in the form of differing standards or carbon prices within APEC, hindering trading on a unified platform. Addressing this requires collaborative efforts in science, technology, and innovation among APEC members to develop a cohesive strategy for progress.

The World Café method employed during the final parallel session on decarbonization policies reflects APEC's commitment to inclusivity and collaboration in addressing complex challenges. By rotating experts within set time limits, the method ensures that a diverse range of voices and viewpoints are heard and integrated into the discussion.

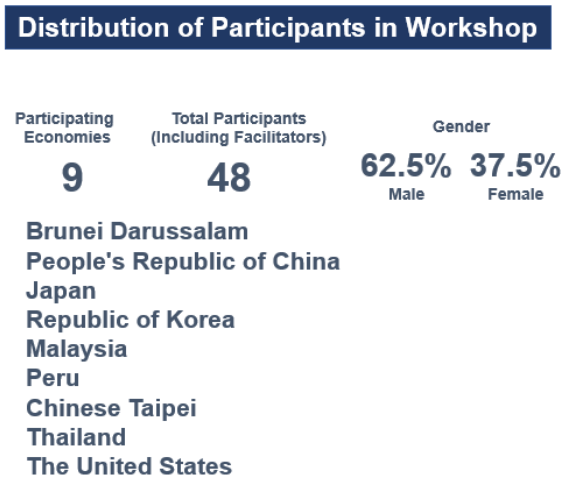
The focus on decarbonization policies highlights APEC's recognition of the urgent need for concerted action to mitigate climate change and achieve sustainable development goals. As member economies work towards formulating and implementing policies to reduce greenhouse gas emissions, the diversity of approaches and strategies within APEC becomes apparent. The World Café method provides a platform for exchanging insights, sharing best practices, and identifying areas for collaboration and capacity-building to accelerate progress towards a sustainable, low-carbon future.

Session 3: Visiting real case This provided participants with the opportunity to gain practical insights through a site visit, where they interacted with local entrepreneurs involved in sustainable tourism with effective waste management. This firsthand experience offered valuable perspectives on the importance of preserving local species and ecosystems for sustainable tourism development.

As the event draws to a close, it is evident that the knowledge gained, and connections forged will serve as valuable assets in shaping future initiatives aimed at fostering sustainable tourism and biodiversity conservation efforts in Thailand and beyond.

Distribution of Participants in Workshop

The workshop included participants from nine economies: Brunei Darussalam; People's Republic of China; Japan; Republic of Korea; Malaysia; Peru; Chinese Taipei; Thailand; The United States. The total participation was 48 individuals, with 62.5% male and 37.5% female attendees. The entirety of the event was recorded for documentation purposes.



Participants' dashboard in the Foresight Workshop

The success of the event can be attributed to the active participation and diverse perspectives brought forth by the attendees. The dashboard of participants, reflecting a broad spectrum of expertise and backgrounds, further enriched the discussions and contributed to the generation of actionable recommendations for APEC to achieve net-zero emissions/ carbon neutrality.

4. FINDINGS AND RECOMMENDATIONS

This section offers a concise overview of key findings and recommendations pertaining to each net zero emissions / carbon neutrality strategy and its subgroups. It emphasizes the significance of insights gathered from experts participating in the Delphi survey and foresight workshop, as well as the proposed actions stemming from these insights.

1) ENERGY DEMAND MANAGEMENT

Energy demand management encompasses strategies and practices aimed at efficiently controlling and reducing the energy needed to fulfill diverse requirements across residential, commercial, and industrial sectors. It entails implementing measures to balance energy supply and demand, mitigate peak energy consumption, and improve overall energy efficiency. Despite the maturity of some technologies that may not be considered appealing, they remain powerful contributors to sustainable energy consumption, ensuring reliability while minimizing environmental impact.

1.1 Energy Efficiency

Energy efficiency refers to the process of using less energy to perform the same task or achieve the same outcome. It involves adopting technologies, practices, and measures that reduce energy waste while maintaining or enhancing productivity and comfort.
The APEC Expert Group on Energy Efficiency and Conservation (EGEEC) was established by the APEC Energy Working Group (EWG) in 1993 to assist in achieving energy security, advance economic and social well-being, and realize environmental benefits in the Asia-Pacific region through energy conservation and the application of energy-efficiency practice and technologies.

a. Desired picture in 2050

The future direction of energy efficiency in APEC envisions a fully integrated approach to maximizing the potential of energy efficiency across member economies, with a heightened focus on increasing awareness and action leading up to 2050. There is a recognized need for unanimous agreement on the effectiveness of energy efficiency policies within APEC.

b. Key driving forces/trends

The **trends** in energy efficiency (EE) indicate significant drivers towards its adoption.

- Increasing consumer and societal awareness on EE and sustainability, driven by public pressure on companies for Environmental, social, and governance (ESG) compliance.
- Growing availability of technological solutions and innovations for EE, facilitated by regulatory measures and incentives such as easily identifiable EE products and economies of scale driving down prices, particularly in the solar energy sector.
- Rising demand for energy consumption, evidenced by an expected 3% annual increase in Malaysia, alongside escalating energy prices, prompting companies and society to adopt EE measures to mitigate costs.

c. Strategic issues

- Regulatory and enforcement mechanisms play a crucial role in promoting EE by implementing standards and guidelines for energy-efficient practices in various sectors, such as large buildings, with the involvement of bodies like the Building Energy Code (BEC) for approvals.
- Human behavior is a significant factor affecting EE, highlighting the importance of public awareness campaigns and behavioral change programs to encourage energy-saving habits.

- The public sector's involvement in EE initiatives influences broader impacts on energy consumption patterns and sustainability practices.
- Effective peak demand management strategies are essential for balancing energy supply and demand, reducing strain on the grid, and optimizing overall energy efficiency.
- Differentiated labeling schemes for commercial and residential spaces provide consumers with information on energy performance, enabling informed decisions and incentivizing EE investments.
- Advanced technologies in the industrial sector, including high-tech solutions, contribute to improving energy efficiency and reducing energy consumption.
- The integration of Artificial Intelligence (AI) technology holds promise for enhancing EE by optimizing energy usage through predictive analytics and automated control systems.
- Subsidies for green technology and incentives for technology transfer facilitate the adoption of EE solutions by reducing financial barriers and promoting knowledge exchange between economies and industries.

d. Strategic collaborations

Strategic collaboration in energy efficiency issues within APEC can be achieved through a multi-faceted approach:

- Governance: Establishing governance structures and frameworks for overseeing and coordinating energy efficiency initiatives across member economies.
- Regulatory Frameworks and Standards: Developing and harmonizing regulations and standards, including labeling schemes for energy-efficient products and building codes to promote sustainable construction practices.
- Incentive Mechanisms: Implementing incentives such as technology transfer programs, research and development (R&D) tax credits, and investment tax credits to spur innovation and investment in energy-efficient technologies.
- Education and Awareness: Conducting educational campaigns and raising awareness about the importance of energy efficiency among stakeholders, including policymakers, businesses, and the general public.
- Financial Mechanisms for Industrial Sector: Establishing financial mechanisms to support energy efficiency projects in the industrial sector, particularly for small and medium-sized enterprises (SMEs) that may face financial constraints.
- Monitoring and Evaluation (M&E): Developing robust M&E frameworks to track the progress and impact of energy efficiency initiatives and identify areas for improvement.
- Sustainability Index: Creating a sustainability index to assess and benchmark the energy efficiency performance of APEC economies, fostering competition and driving continuous improvement.
- Green Activities for Investors: Encouraging green investment activities by providing funding, improving infrastructure, implementing supportive policies, and developing skills and technologies conducive to energy efficiency advancements.

1.2 Energy Intensity

Energy intensity refers to the amount of energy required to produce a unit of output, such as economic output measured by Gross Domestic Product (GDP), industrial production, or other measurable indicators. It is a metric used to assess the efficiency of energy use in relation to economic or productive activities. Lower energy intensity indicates a more efficient use of energy resources.
In 2007, APEC leaders proposed a regional goal to reduce energy intensity by at least 25 percent by 2030. In 2011, APEC leaders set a higher target to reduce energy intensity by at least 45 percent by 2035 (Honolulu Declaration).

a. Desired picture in 2050

- Future Vision: APEC aims to push forward a substantial 45% reduction in energy intensity (EI) by 2035, building upon the baseline. However, due to climate change drivers, it is necessary to revise the target to be more aggressive.
- Concept: EI reflects the inverse relationship between GDP (income) and energy consumption, where reducing energy consumption while maintaining or increasing income levels is the objective.
- Objective: Achieving this vision entails decoupling economic growth from energy consumption, leading to enhanced energy security and environmental sustainability across the APEC region.

b. Key driving forces/trends

- Energy Efficiency (EE) is central to this vision, calculated as the ratio of energy consumption to GDP, with strong emphasis on decreasing fossil fuel dependency while maintaining economic prosperity.

c. Strategic issues

- Updating regional energy intensity (EI) targets within APEC is vital for aligning with evolving global energy trends and commitments.
- This strategic issue involves developing and implementing updated regulatory measures, including energy efficiency standards and emissions reduction targets.
- Collaboration and knowledge-sharing among member economies are essential to accelerate progress towards achieving updated regional EI targets.
- By prioritizing the establishment of new regional EI goals, APEC can lead in advancing sustainable development and addressing climate change challenges in the Asia-Pacific region.

d. Strategic collaborations

- Set “Green EI” to prioritize initiatives promoting energy efficiency and renewable energy sources to achieve environmentally sustainable energy intensity.
- High Technology Demonstration: Through joint initiatives, showcasing advanced technologies for energy efficiency allows for knowledge exchange and inspires broader adoption, driving progress towards sustainable development goals.
- Social Perspectives: Incorporating social considerations ensures that energy efficiency initiatives are inclusive and responsive to the needs of diverse communities, promoting equitable access and sustainable development outcomes.

1.3 Electricity Demand

Electricity demand refers to the quantity of electrical energy required by consumers, businesses, industries, and other entities within a timeframe.

a. Desired picture in 2050

- APEC's sustainable electricity future through cross-border trading : As APEC economies pursue net zero emissions/ carbon neutrality, addressing rising sustainable electricity demand is paramount. To achieve this, APEC envisions cross-border trading of electricity as a solution. This approach leverages diverse energy resources across economies, optimizing supply and reducing carbon emissions. By sharing renewable energy surpluses and fostering regional cooperation, APEC promotes sustainability, resilience, and economic growth. Through smart grid technologies and market integration, cross-border trading drives innovation, affordability, and energy security, aligning with APEC's commitment to a cleaner, more sustainable energy future.

b. Key driving forces/trends

- Experts are highly concerned about the rising demand for electricity, which is becoming the predominant form of energy in APEC economies as they strive to achieve net zero emissions/ carbon neutrality.

c. Strategic issues

- Consumption trends underscore the significance of electricity demand in APEC, highlighting the need to raise awareness among individuals about the importance of transitioning from fossil fuels to electricity.

d. Strategic collaborations

- Transition Policies: Collaborative efforts are needed to develop and implement transition policies, focusing on governance structures, capacity building of governments, and institutional frameworks to facilitate the transition towards sustainable energy systems.
- Technology and Innovation Transfer, Knowledge Sharing: Promoting technology and innovation transfer, as well as knowledge sharing initiatives, will accelerate the adoption of clean energy technologies and practices across APEC member economies.
- Education Implementation: Implementing educational programs and initiatives to raise awareness and build capacity among stakeholders regarding the importance of sustainable energy practices and the transition to clean energy sources.
- Exchange Technology: Facilitating technology exchanges and partnerships among APEC economies will enhance access to clean energy technologies and solutions, fostering innovation and collaboration in the renewable energy sector.
- APEC Aging Society: Addressing the energy needs of an aging society within APEC requires collaborative efforts to develop tailored energy solutions, including energy-efficient infrastructure and services, to meet the evolving needs of elderly populations while promoting sustainability and resilience.

2) ENERGY TRANSITION

APEC relies heavily on fossil fuels for its energy needs, comprising 86% of total primary energy supply and 75% of electricity supply. Despite efforts to transition to clean energy sources like renewables and hydrogen, managing these shifts poses significant challenges due to technological, socio-economic, and environmental complexities, along with uncertainties about future developments.

2.1 Electricity Supply

Electricity supply refers to the network of components needed to generate, transmit, distribute, and supply electric energy to various demand sectors of the economy. It comprises of an electricity-generation system that converts primary energy (fossil and non-fossil) into electrical energy, and transmission-and-distribution systems (centralized and decentralized networks) to deliver electrical energy for final usage.

a. Desired picture in 2050

- The future envisions the widespread adoption of smart grids tailored to meet demand efficiently and sustainably. These advanced grid systems integrate renewable energy sources seamlessly, ushering in a new era of green electricity supply. Through the expansion of renewable energy infrastructure, our vision is to create a sustainable energy landscape where clean and reliable electricity is accessible to all, contributing to a healthier planet and a brighter future for generations to come.

b. Key driving forces/trends

- A strong driver is the earlier phase-out of fossil fuel infrastructure, possibly before its economic lifespan.

c. Strategic issues

- Resource Scarcity for Renewable Energy (RE) Technology: APEC faces the challenge of resource scarcity, particularly in mineral and material processing crucial for renewable energy technologies. Addressing this challenge is critical to ensure the sustainable and scalable deployment of clean energy solutions across member economies.
- Expansion of Green Electricity Supply: APEC emphasizes the strategic importance of expanding the provision of green electricity supply. This expansion is vital for accelerating the transition to sustainable energy systems within the region, fostering environmental sustainability, and effectively mitigating the impacts of climate change.

d. Strategic collaborations

- Investment in New Technology (Green Finance): APEC emphasizes the importance of investing in new technologies through green finance mechanisms to support clean energy development. Collaboration is essential to ensure effective funding allocation.
- Funding Mechanisms: Developing effective funding mechanisms is crucial for mobilizing resources to support sustainable energy projects within APEC. Collaboration among member economies is necessary to create diverse funding mechanisms.
- Market Structure: APEC recognizes the importance of establishing conducive market structures to incentivize investment in sustainable energy. Collaboration between member economies is vital to harmonize regulatory frameworks and promote innovation in the energy sector.

2.2 Hydrogen Economy

Hydrogen economy refers to an economy that relies on hydrogen as the commercial fuel to deliver a substantial fraction of an economy's energy services. It comprises of a linked network of chemical processes that produce hydrogen (e.g., electrolyze), store hydrogen chemically or physically, and convert the stored hydrogen to electrical energy at the point of use. It is considered as the potentially key energy source to low-carbon energy systems in the hard to-abate sectors such as cement, steel, and long-haul transport.

a. Desired picture in 2050

- In envisioning the future, experts in the workshop have painted a compelling picture of 2035, where Low Carbon Hydrogen plays a central role within APEC. This vision encompasses a landscape where hydrogen, produced with minimal carbon emissions, serves as a cornerstone of energy systems. Through collaborative efforts and technological advancements, this vision underscores a sustainable and decarbonized future, where hydrogen emerges as a key enabler of clean energy transition across APEC economies.

b. Key driving forces/trends

- Hydrogen energy plays roles in decarbonizing hard-to-abate sectors within APEC economies.
- It enables deep decarbonization in industries and complements sectors such as heavy transportation, while also enhancing energy system stability through seasonal storage.
- Green hydrogen is essential for hard-to-reduce industries to achieve zero-carbon production, crucially supporting their development under zero-carbon constraints.
- The hydrogen industry has experienced rapid growth in recent years, marked by significant technological advancements, instilling confidence in its future utilization within hard-to-reduce industries.

c. Strategic issues

- Green Hydrogen: Promoting the production and utilization of green hydrogen as a sustainable energy source, requiring investment in renewable energy technologies and infrastructure.
- Hydrogen Fuel Cells and Mobility: Encouraging the adoption of hydrogen fuel cells and mobility solutions for vehicles, facilitating the transition towards cleaner transportation and power generation.
- Behavioral Shift: Addressing behavioral patterns and consumer preferences to foster acceptance and adoption of hydrogen-based technologies and solutions.
- Green Electricity and Electrolysis: Investing in green electricity and electrolysis technologies to enable low-cost hydrogen production, enhancing the viability of hydrogen as an energy carrier.
- Key Sectors for Hydrogen: Identifying and prioritizing key sectors such as fuel cells, power generation, and industrial applications for targeted deployment of hydrogen technologies.
- High production costs pose a major barrier to the development of the hydrogen economy, presenting significant challenges for its widespread adoption. Economic viability is crucial for scaling up the utilization of green hydrogen.

d. Strategic collaborations

- Transitioning within APEC from low carbon hydrogen to green hydrogen signifies a shift towards cleaner and more sustainable production methods. While low carbon hydrogen reduces emissions, green hydrogen is produced using renewable energy sources like wind or solar power through electrolysis. This transition is pivotal for achieving carbon neutrality and reducing greenhouse gas emissions in sectors reliant on hydrogen within the APEC region, driving the adoption of renewable energy and fostering innovation in clean energy technologies.
- Certificates for hydrogen and its derivatives: APEC collaboration is vital for establishing international standards and protocols for hydrogen certificates, ensuring consistency and recognition of green or low carbon hydrogen across member economies.
- Market demand and public awareness: APEC collaboration can drive initiatives to increase awareness and stimulate market demand for hydrogen

technologies through joint public awareness campaigns, market studies, and information sharing.

- Investment in research and development: APEC collaboration fosters joint research and development efforts in areas such as alkaline fuel cells and automotive fuel cells, leveraging collective expertise and resources to accelerate technological advancements.
- Investment in manpower development: APEC collaboration supports capacity building and skills development initiatives to cultivate a skilled workforce for the hydrogen industry, promoting knowledge sharing and training programs across member economies.
- Mapping out hydrogen economy technologies: APEC collaboration facilitates the exchange of knowledge and best practices in hydrogen technology mapping, enabling member economies to identify opportunities for collaboration and prioritize research and development efforts.
- Introducing green hydrogen certificates: APEC collaboration can lead to the establishment of harmonized certification mechanisms for green hydrogen, facilitating international trade and promoting the adoption of sustainable hydrogen production practices.
- Advancements in hydrogen transportation and infrastructure: APEC collaboration promotes joint initiatives to develop efficient hydrogen transportation systems and infrastructure, including new materials and fueling stations, to support the widespread adoption of hydrogen as an energy source across member economies.

3) GREEN ECONOMY

The green economy, emerging as key to sustainable development, focuses on balancing economic growth, social equity, and environmental protection. It aims to minimize ecological risks and scarcities across sectors such as industry, agriculture, waste management, and tourism, fostering a transition towards a sustainable future without compromising the planet's health.

3.1 Industrial Processes

In a green economy, industrial processes refer to the methods and techniques used in manufacturing and production that prioritize sustainability, resource efficiency, and environmental responsibility. These processes are designed to minimize negative environmental impacts while optimizing resource utilization and promoting cleaner, more efficient production methods.

a. Desired picture in 2050

- In 2050, the industrial landscape is transformed by sustainability and innovation, driven by enhanced carbon pricing and market mechanisms, alongside significant cost reductions in green technologies like hydrogen and CCS/CCUS. International collaboration increases, supported by climate finance treaties and regulations for green products, lowering the costs of green technology. Technological advancements are widespread, from the development of innovative, sustainable materials to the increased use of AI, digitalization, and big data. This era is marked by a profound shift towards a green economy, emphasizing global cooperation, the modernization of legal frameworks, and investment in green technologies. Societal and organizational changes foster a diverse, decentralized approach to innovation, underpinned by a whole-of-economy approach, ensuring a sustainable, equitable, and economically vibrant future.

b. Key driving forces/trends

- The key trends shaping industrial processes revolve around enhancing supply chain resiliency and addressing the growing awareness for sustainable and equitable development, including prioritizing the inclusion of local and indigenous people. Economic pressures such as limited technology transfer, inflation-related reduction of living standards, and an increased consumer demand for green products underscore the shift towards sustainability. The implementation of measures like the Carbon Border Adjustment Mechanism (CBAM) and facing trade barriers further reflect the urgency for industries to adapt. This global shift towards sustainability and innovation is highlighted by higher carbon pricing, technological advancements, and a demand for green products, emphasizing the necessity for global cooperation, legal modernization, and focused strategies on green funding and technology investment to navigate towards a sustainable industrial future.

c. Strategic issues

- The strategic issues facing industrial processes revolve around a framework designed to boost efficiency, innovation, and sustainability. This involves fostering cross-border cooperation, modernizing laws, and establishing regional carbon markets for global governance. It emphasizes securing resources through green funding for SMEs, protecting intellectual property, and investing in technologies like AI and robotics to drive innovation. The strategy also focuses on developing human resources and education to ensure a skilled future workforce and addresses ethical and safety concerns in technology use, particularly AI. This holistic approach seeks to balance economic growth with environmental and social responsibility

d. Strategic collaborations

- The strategic collaboration in industrial processes focuses on APEC-wide initiatives enhancing sustainability and innovation. It includes a platform for data and technology transfer, technology conferences encouraging investor engagement, and the establishment of the APEC Low Carbon Industrial Club to support green technologies. Policy dialogues aim at modernizing legal frameworks for a green economy and reforming regulations. Educational strategies involve interdisciplinary courses on APEC issues, fellowships for green talents, and training programs for green innovation and entrepreneurship. Funding for research and innovation is provided through grants, paralleling the EU's Horizon program. Carbon emission reduction efforts are bolstered by the APEC Voluntary Emission Reduction Scheme, a regional carbon market trading platform, and a policy to increase carbon credit prices for developing economies within APEC.

3.2 Agricultural Practices

Agricultural practices in a green economy refer to the adoption of sustainable and environmentally friendly technologies and methods within the agricultural sector. These practices prioritize the efficient use of resources, minimize negative environmental impacts, promote biodiversity, and ensure long-term food security while supporting economic viability for farmers.

a. Desired picture in 2050

- By 2050, agriculture transforms into a technologically advanced, eco-friendly, and resilient sector. Precision farming becomes the norm, utilizing AI, sensors, and drones to optimize every farming stage for efficiency and yield. The circular economy approach minimizes waste and recycles resources, enhancing sustainability. Vertical farming proliferates in urban areas, using less water and

space to produce food year-round. Biotechnology and genetic tools like CRISPR ensure crops are climate-resilient, while AI and machine learning optimize farming practices. Global cooperation and technological advancements secure food production and accessibility, ensuring a stable food system. Access to farming information is democratized, empowering farmers globally. This future of agriculture is not just about food production but nurturing ecosystems, supporting communities, and sustaining economies, linking technology with ecological and social sustainability.

b. Key driving forces/trends

- The key driving forces behind future agricultural practices include addressing nutritional needs and the challenges of an aging population, limited arable land, and the impacts of urbanization and climate change, such as flooding and drought. Agile adaptations in agriculture, like the integration of solar energy through Agrivoltaics, respond to these pressures. Population dynamics play a significant role, with increases in global population and growth concentrated in developing economies, contrasted by decreases in advanced economies. Sustainable land management and the recovery and reuse of land are essential for sustaining future food production and environmental health.

c. Strategic issues

- The strategic issues of agricultural practices focus on improvements across several key areas. Research and development are targeted towards diversifying agriculture through initiatives like agroforestry and green vaccination. There's a significant emphasis on supporting farmers via technical assistance and tailoring technology to fit local needs. Optimizing the market and supply chain is critical, with strategies aimed at aligning future markets to be farmer-accessible, balancing supply and demand, and establishing supply chain agreements. Policy and regulation enforcement includes zoning, planning, and specific activities such as burning regulations. This shows a comprehensive approach towards sustainable and efficient agricultural practices.

d. Strategic collaborations

- Strategic collaboration in agriculture within the APEC framework aims to enhance trade, sustainability, and innovation. Initiatives include establishing an APEC Agriculture Free Trade Market and promoting environmentally certified brands and Geographical Indication (GI) products. A networking platform facilitates information sharing and showcases good agricultural practices, supported by programs like the Big Brother Program for technology transfer and capability building. Policy efforts focus on creating a regional committee for burning restrictions, guidelines for an APEC-wide agricultural code of conduct, and laws to prevent unfair contract farming. Cross-sectoral and cross-border collaborations are encouraged, integrating agriculture with energy, digital, and health sectors across APEC economies. Educational and capacity-building measures include making applications more accessible through language translation, creating an APEC University Network, providing grants for sustainable practices, and establishing an APEC Agricultural Tech Transform Center.

3.3 Waste Management

Waste-disposal management can be defined as the actions required to manage wastes from the first production stages up to the final disposal stage. This includes collection, transportation, treatments, and disposal of waste along with monitoring and regulating. It also encompasses the legal and regulatory frameworks that are related to waste management, including guidance on recycling. Wastes are expensive and sometimes unavoidable results of human activities, which could have serious consequences on the environment and the quality of life if not adequately addressed. To achieve green growth, investments on environmental management should be an engine of economic growth. Modern waste-management practices involve not only the treatment of wastes but also the conversion into useful substances.

a. Desired picture in 2050

- In 2050, the vision for waste management in APEC entails a paradigm shift towards a circular economy model where waste is minimized, resources are conserved, and environmental impacts are mitigated. Advanced technologies and innovative solutions are integrated into waste management practices, leading to zero waste generation and optimal resource utilization. Waste is viewed as a valuable resource rather than a burden, contributing to sustainable development and environmental stewardship across APEC economies.

b. Key driving forces/trends

- Key trends in waste management within APEC include a growing recognition of plastic pollution as a significant challenge and driver for sustainable waste management practices. There is an increasing focus on diversifying waste sources to include alternative materials such as agricultural waste, timber, and recycled materials. Additionally, there is a trend towards the implementation of reverse logistics systems to streamline waste collection processes and promote efficient resource recovery and recycling.

c. Strategic issues

- Strategic issues facing waste management in APEC include the ineffective implementation of waste management policies and the prevalence of plastic pollution, hindering progress towards achieving net zero emissions/ carbon neutrality. There is also a need to transition towards sustainable materials from alternative sources to reduce reliance on single-use plastics and other non-recyclable materials. Additionally, the lack of robust reverse logistics systems poses a challenge in accelerating waste collection processes and promoting circular economy principles.

d. Strategic collaborations

- To address these challenges and capitalize on opportunities, strategic collaboration within APEC is essential. Establishing a platform for cross-border waste management initiatives will facilitate international collaboration and knowledge sharing among member economies. This platform can serve as a repository for digital data on waste management, enabling data-driven decision-making and promoting best practices across APEC. Capacity building efforts in eco-design, regulation, and standards modernization are also critical components of strategic collaboration, fostering innovation and sustainability in waste management practices across APEC economies.

3.4 Green Tourism

Green tourism, also known as sustainable tourism, eco-tourism, or responsible tourism, is a type of travel and tourism that focus on minimizing the negative impacts of tourism and promoting environmental conservation, cultural preservation, and social responsibility. Green tourism is also well known as small-scale tourism that encourages people to visit natural areas and minimize the impacts of tourism on the environment. The term is used for businesses with environmentally friendly activities. The rising demand for sustainability is not specific to the tourism industry but is part of a larger movement towards a greener economy.

a. Desired picture in 2050

- In 2050, the vision for tourism in the APEC region sees a transformation towards sustainable and green tourism practices. Tourist destinations prioritize environmental conservation, cultural preservation, and community engagement, offering unique and authentic experiences that minimize negative impacts on local ecosystems and communities. Green tourism becomes the norm, with travelers embracing sustainable travel choices and seeking destinations that prioritize environmental and social responsibility.

b. Key driving forces/trends

- Key trends in tourism within the APEC region include growing concerns about the environmental and social impacts of tourism activities. There is an increasing demand for green and sustainable tourism experiences, driven by changing consumer preferences and heightened awareness of environmental issues. Additionally, logistics and transportation emerge as critical bottlenecks hindering the transition towards green tourism, necessitating innovative solutions to improve accessibility and minimize environmental footprint.

c. Strategic issues

- Strategic issues facing tourism in the APEC region include challenges related to carrying capacity management, waste management, and the lack of availability of green products and services. Local authorities struggle to effectively manage tourist expectations while preserving natural and cultural heritage sites. Additionally, inadequate transportation infrastructure and logistical support hinder efforts to promote sustainable tourism practices and facilitate green tourism transformation.

d. Strategic collaborations

- To address these challenges and capitalize on emerging opportunities, strategic collaboration within APEC is imperative. A concerted effort is needed to review and update existing arrangements to accommodate more green and sustainable tourism establishments. This includes establishing registration platforms for green tourism businesses, providing green finance options for micro, small, and medium-sized enterprises (MSMEs), and implementing educational programs to promote the concept of 'green spirituality' among both locals and tourists. By fostering collaboration among member economies, APEC can drive the transition towards sustainable and responsible tourism practices in the region.

4) Carbon emissions sinks

Besides mitigation and adaptation measures, carbon emission sinks are crucial in battling climate change by absorbing and storing CO_2 for extended periods using natural or artificial reservoirs. These sinks function by sequestering more CO_2 than they emit. Carbon capture technology has gained significant interest in the past years from many APEC economies, led by the US.

4.1 CARBON CAPTURE, UTILIZATION, AND STORAGE (CCUS)

- *Carbon Capture, Utilization and Storage (CCUS) refers to the process of capturing CO_2 emissions from sources such as fossil power generation and industrial processes and either storing captured CO_2 in permanent geological storages or using captured CO_2 for various applications such as synthetic fuels and building materials.*
- *Carbon Capture and Storage (CCS) is the process of capturing, transporting, and storing CO_2 at a long-term storage location.*
- *Carbon Capture and Utilization (CCU) is the process of capturing CO_2 for further use in creating CO_2-based products while maintaining the overall carbon neutrality of the production process.*

To obtain detailed opinions and insights for CCUS, discussions and results are divided into CCS and CCU as follows.

Carbon Capture and Storage (CCS)

a. Desired picture in 2050

- CCS plays a significant role in achieving net zero emissions/ carbon neutrality. Large-scaled CCS plants using green energy can store up to 15% of CO_2 emitted by all APEC economies or up to 20 gigatons of CO_2 per year, with transboundary and transparency cooperation among APEC economies.

b. Key driving forces/trends

- Cost of carbon capture will go down significantly.
- CCS-as-a-Service with international safety standard will create a new business.
- Global Emissions Trading System or APEC Emission Trading System will help accelerate CCS implementation and CCS-as-a-Service.
- Direct-Air-Capture will gain momentum for CO_2 capture.
- Due to limitation on appropriate storage sites, innovative ways to capture and store CO_2 such as using seaweed can be a good candidate.

c. Strategic issues

- Investment: Since constructing and operating CCS sites require monumental amount of fund, investment, especially from governments, is critical for driving CCS from testing phase to actual implementation phase. This causes financial challenges to many economies in APEC.
- Technology: Currently, the cost of CCS technology is extremely high. Thus, low-cost emerging technology is highly needed. This would help reducing the cost of energy for households when CCS is implemented.
- Infrastructure: Limitation on appropriate storage sites causes immense challenges for CCS implementation. Besides, large-scale CCS plants capable of storing gigatons of CO_2 are required to make significant impact.
- Regulations: There are massive challenges for transboundary and transparency cooperation among APEC economies.
- Policy: Dedicated policy is essential to support CCS deployment.
- Standards: Due to varieties of risks in operating CCS plants such as CO_2 leakage from sites and natural disasters, safety standards are critical.
- Public perception: Public perception on CCS is important to get support from the public. Since most people do not know about benefits and risks of CCS, public awareness is necessary.
- Manpower: To strengthen skills and knowledge regarding CCS for existing workforces, upskill and reskill are required.

d. Strategic collaborations

- Alignment of APEC strategy in CCUS: A collaboration roadmap for CCUS development and implementation in APEC should be drafted to provide a framework, guideline, and timeline for essential collaborations in APEC such as knowledge sharing, capacity building, R&D collaboration, and technology transfer.
- Knowledge sharing: In order to help many economies catching up with leading economies in CCS development and implementation, knowledge sharing in key areas is critical. Examples of subjects include essential scientific knowledge and good practices on CCS pilot plant operation.
- R&D collaboration: To accelerate the discovery of breakthrough technologies and innovations, APEC economies should collaborate on key research topics such as high storage efficiency, low-cost technologies, safety.
- Capacity building: Since CCS development and deployment requires some new skills, knowledge, and abilities, capacity building programs are beneficial for strengthening capability of APEC economies.
- Infrastructure sharing: Infrastructure sharing can lead to a new business model such as CCS-as-a-Service. Economies with limitation on CO_2 storage sites can negotiate with economies offering CCS-as-a-Service.
- Technology transfer: Many APEC economies require advanced technologies on CCS to develop and operate their own CCS plants. Therefore, technology transfer mechanism within APEC is a crucial topic worth discussing.

Carbon Capture and Utilization (CCU)

a. Desired picture in 2050

- Utilization of CO_2 in carbon recycling and upcycling within enormous APEC markets driven by large enterprises and SMEs is achieved.

b. Key driving forces/trends

- Green markets are expanded due to enforced green measures. such as Carbon Boader Adjustment Mechanism (CBAM) introduced by the EU and other future measures from non-EU economies.
- Converging technologies such as those combining artificial intelligence and chemicals can help create new technologies and products.

c. Strategic issues

- Technology: At present, most technologies for CCU implementation are still immature. Examples of required technologies include catalyst technologies and CO_2 conversion.
- Market demands: Currently, demands for green products from CO_2 is insignificant. However, market demands are expected to grow in the future, especially for construction and aviation sector.
- Investment: Since the current market size is unappealing due to limited demands, firms are reluctant to invest in technologies and develop products. Initial funding is required for firms to compete in the market.
- Incentive: Due to unattractive market demands for products from CO_2 and immature technologies at present, governments should provide incentives to persuade firms, especially SMEs, to participate in the growing market.
- Safety concerns: Products from CO_2 require safety attentions to prevent CO_2 leakage during product lifetime. Hence, creating safety standards is necessary.
- Manpower: Since products from CO_2 vary and require knowledge in different fields, multidisciplinary programs are essential for training workforces.

d. Strategic collaborations

- Market opportunities within APEC: APEC economies account for nearly 40 percent of the global population, and nearly 50 percent of global trade.

Therefore, the market size for products from CO_2 in APEC is expected to be quite large in the future. Setting up an APEC market system for products from CO_2 and facilitating trade can accelerate investment and product development.

- R&D collaborations: Currently, most technology development for CCU is in the initial state. Therefore, research collaborations among APEC economies are preferable to create technology platforms for enterprises, especially SMEs, to apply for commercialization.
- Alignment of CCS and CCU: Since the cost of products involves total costs of overall process, carbon capture and storage should be considered when designing products from CO_2. New businesses within APEC economies could occur from fully deployed CCUS.
- Technology transfer: Technology transfer is essential for strengthening technological capability of enterprises in APEC regarding CCU. Hence, effective technology transfer mechanism should be proposed and agreed upon.
- Knowledge sharing: Scientific knowledge related to CCU should be shared within APEC community using a knowledge sharing platform.
- Capacity building: To prepare new workforces and strengthen capability of existing workforces, reskilling, upskilling, and creating new skills for CCU implementation are required.

4.2 Land-use Practices

Land-use practices for net zero emissions/ carbon neutrality refer to activities such as reforestation, afforestation, agroforestry, and carbon farming which is a holistic farm approach to optimizing carbon capture and storage by implementing practices that can improve the rate at which CO_2 is removed from the atmosphere and stored in plants and/or soils. Net zero emissions/ carbon neutrality require transformative changes in land use for direct GHG reduction, especially from the agricultural sector and for carbon sequestration.

a. Desired picture in 2050

- Land-use practices contribute substantially to net zero emissions/ carbon neutrality with well-balanced land-use transitions and effective law enforcement.

b. Key driving forces/trends

- Lack of political continuity leads to ineffective long-term policy for land-use practices.
- Land-use changes cause severe biodiversity loss resulting in climate change.
- Corporates tend to support environmental activities such as afforestation and reforestation for their corporate social responsibility (CSR) without sufficient knowledge of suitable species and life cycle of plants.

c. Strategic issues

- Incentives and compensation: Unattractive incentive schemes discourage farmers to adapt their ways of farming and living. Besides, fair compensation for private landowners to help drive land-use practices policy is required.
- Knowledge: Lack of knowledge in species and life cycle of plants can cause negative impact such as planting plants that produce volatile organic compounds (VOCs), which can indirectly cause climate change.
- Carbon trading: Currently, demands for carbon credits in each APEC economy are limited. Besides, carbon prices are unappealing with high cost of carbon credit verification. These pose big challenges to setup a well-functioning carbon market in most economies.
- Land ownership rights: Clarity of land ownership rights is important for designing land-use practices policy and tracking land-use changes.

- Funding for R&D: Insufficient and discontinuous fund supports result in discontinuity of new discoveries and knowledge sharing opportunities.

d. Strategic collaborations

- APEC carbon market: Due to unattractive carbon prices and limited demands for carbon credits in each economy in APEC, a common APEC carbon market with reasonable carbon prices and acceptable cost of carbon credit verification is desirable. This allows seamless carbon trading between buyers and sellers across APEC economies.
- Knowledge sharing: Dynamic knowledge sharing that combines modern knowledge and traditional knowledge from each economy provide information and good practices that APEC economies can learn from each other and adapt for the benefits of their own economies. An example of shared knowledge could be a “Mother Nature Catalog” containing information of plants and their capacity to absorb greenhouse gases.
- R&D collaboration: A common fund should be given for collaborative research on forests and common technologies such as low-cost surveillant technologies required to prevent deforestation, track wildfires, and track land-use changes.
- Capacity building: To accelerate restoration of forest ecosystems, capacity building for researchers and practitioners in new method such as the framework species method (FSM) is necessary.
- Registration of land-use changes: Tracking land-use changes is critical to control greenhouse gas emissions and protect biodiversity loss. Therefore, a standardized registration system for land-use changes is essential to collect information and use for planning.

5) OFFSET POLICIES

The discussion on the off-set policies revolves Emission Trading Schemes (ETS) and Renewable Energy Certificates (RECs) as mechanisms to meet emission reduction goals. While the EU's Carbon Border Adjustment Mechanism (CBAM) aims to regulate imported product pricing for emission reduction, potentially disrupting global supply chains. APEC economies face the challenge of implementing competitive policies to address this, particularly as products exceeding GHG limits may require offsetting emissions with CBAM Certificates, posing pricing implications and favoring EU goods. Calculating import emissions from both direct and indirect sources adds complexity to APEC's adaptation efforts.

5.1 Clean Development Mechanism (CDM)

Clean Development Mechanism (CDM) refers to strategies employed by economies to achieve their greenhouse gas (GHG) reduction objectives by investing in emission-reduction projects located in other economies. These corresponding initiatives generally generate carbon credits, which can be traded domestics or internationally.

a. Desired picture in 2050

- Carbon trading in the APEC region is expected to be mature and strong by 2050, contributing successfully to global efforts to address climate change. Carbon trading emerges as a critical method for lowering greenhouse gas emissions, rewarding emission reduction initiatives, and accelerating the transition to a low-carbon economy. The ETS promotes international cooperation and collaboration by allowing both industrial and non-industrial economies to participate in emissions reductions and exchange emission

allowances, resulting in considerable reductions in carbon emissions across the APEC region.

- In 2050, APEC envisions a pioneering approach to carbon pricing with the introduction of the Hybrid Market. This innovative concept combines emissions trading and carbon taxation, offering a dynamic solution to address climate change. The Hybrid Market fosters sustainable development, driving investments in emissions reduction and incentivizing low-carbon innovation across industries, ensuring a resilient, low-carbon future for APEC economies.

b. Key driving forces/ trends

- Key trends in carbon trading within the APEC region include a strong push for emissions trading systems driven by international agreements such as the Paris Agreement. Article 6 of the Paris Agreement facilitates carbon trading, providing opportunities for economies to participate in emissions reduction efforts through market-based mechanisms.

c. Strategic issues

- Market Dynamics
  - Ensuring compliance with carbon trading regulations, bridging the gap between corporate and trade prices.
  - Addressing challenges in voluntary carbon markets, where prices tend to remain low.
  - Integrating various market mechanisms to optimize carbon trading effectiveness.
- Quality-based Carbon Credits
  - Establishing standards for carbon credits based on emission quality to enhance their credibility and value.
- Social Impacts:
  - Addressing the social implications of carbon trading, including its effects on communities and vulnerable populations.

d. Strategic collaborations

- APEC Intermediate Broker: Facilitating collaboration among APEC economies by serving as an intermediary in carbon trading transactions, promoting transparency and efficiency in the market.
- Standards: Developing common standards and protocols for carbon trading within APEC, ensuring consistency and credibility in emissions reduction efforts across member economies.
- Global Market Integration: Fostering collaboration with global partners to integrate APEC carbon trading initiatives into the broader international carbon market, promoting alignment and coherence in climate action strategies.
- Hybrid Market (Trade and Tax): Introducing innovative market mechanisms such as the Hybrid Market, which combines elements of emissions trading and carbon taxation, to drive sustainable development and incentivize low-carbon innovation.
- Technology, Cost, and Carbon Price Alignment: Collaborating on technology development, cost management strategies, and carbon pricing mechanisms to ensure alignment with diverse economic contexts and enhance the effectiveness of carbon trading initiatives within APEC.
- The APEC collaboration is important. Member economies should establish common standards for carbon trading, ensuring alignment with international verification standards and fostering transparency. Introducing a Hybrid Market, combining emissions trading and carbon taxation, could enhance carbon trading effectiveness. Through collaboration, APEC can advance carbon trading mechanisms and expedite progress towards carbon neutrality and climate resilience.

5.2 Cross Border Adjustment Mechanism (CBAM)

The EU has policies and guidelines to reduce Greenhouse Gas (GHG) emissions through a tax mechanism called "the Cross Border Adjustment Mechanism (CBAM)" by controlling the pricing of some imported products to prevent the import of high GHG emissions into the EU. Non-EU enterprises must improve their production processes to be environmentally friendly. This can cause disruption in the global supply chain, especially for industries that rely on the import or export of products with high GHG emission. Each economy must have feasible policies to maintain competitiveness in international markets. If the products imported into the EU have GHG emissions that are higher than the specified value, importers will have to offset GHG by purchasing CBAM Certificates as proof of payment according to EU standards, resulting in higher prices of products. Consumers within the EU may turn to EU-made products more due to lower prices. The GHG emissions of imported goods (Embedded Emission) are calculated from direct GHG emissions generated from the production process and indirect GHG emissions generated from electricity used in the manufacturing process of that product.

a. Desired picture in 2050

- It is likely that all major industries will be included in CBAM, thus affecting all types of exports. Due to concerns over the success and trade fairness of CBAM and counter measures from other economies, a holistic and harmonized mechanism is envisioned. Furthermore, environmental governance and initiatives to address carbon leakage and promote environmentally friendly practices, possibly through network of platforms for interactions, are desirable.

b. Key driving forces/ trends

- The possibility of CBAM being a trade barrier created for protectionism by developed economies will cause dispute.
- Global concerns over climate change force companies to relocate carbon-intensive industries to appropriate places and adopt cleaner technologies as well as production methods.
- Protesting and raising awareness of greenwashing leads to environmental-friendly products.
- The size of green market is increasing.
- Win-win negotiation practices will bring level playing fields to reach net-zero emissions/ carbon neutrality.

c. Strategic issues

- Policy: For some economies, policy for tackling climate change may not catch up with the current situation (i.e. focusing on carbon emissions while overlooking other pollutants). Also, some policies are arguably contradicted with fair trade conditions.
- Regulations: Due to lack of clear guidelines, there is a need to apply global standards to measure GHG emissions scientifically and accurately for products that are imported into the EU.
- Emissions Trading System (ETS): An effective emission trading system with better GHG and carbon footprint databases is required.
- Technology: There may be technology divides where clean technologies and modes of production are not accessible for some or many economies.
- Investment: Some companies may relocate to less-developed or less-stringent economies (pollution havens).
- Manpower: To assist companies in preparing a CBAM report, governments in many economies need to prepare manpower for auditing and verification of GHG emissions.
- Information: There should be effective and broader data collection and sharing systems to facilitate greenhouse gas emissions and inventory.

d. Strategic collaborations

- Regulations and standards: To drive international cooperation on preventing carbon leakage, harmonized environmental regulations and standards with agreed definitions and terms are essential. In particular, fair and standardized carbon accounting procedures should be discussed.
- Dialogue platforms: Due to different policy and measures in handling CBAM of each economy, dialogue platforms on policy, legal and technical matters are required to provide acceptable solutions. This will create greater negotiation power and leveraging powers regarding CBAM for APEC economies.
- APEC Emissions Trading System: A common ETS with fair carbon prices and acceptable cost for auditing and verification in APEC should be established.
- Capacity building: Demands for environmental experts in various areas such as auditing, and verification are expected to increase in the near future. Therefore, reskilling and upskilling existing experts as well as preparing new ones should be considered.
- Funding: To support local green technology development, sufficient funding should be allocated. Furthermore, green financing should be readily accessible by SMEs in APEC.
- Technology platforms: Platforms for collaborative R&D, technology development and technology transfer should be established.

5. KEY MESSAGES

The key messages from this project can be grouped into five main points..

1) Incorporating decarbonization or accelerating decarbonization technology strategies as primary mission targets of the PPSTI (in the new PPSTI strategic plan) is imperative. This strategic move recognizes the global imperative of reducing greenhouse gas emissions and underscores the pivotal role of science, technology, and innovation (STI) in achieving this goal. By prioritizing decarbonization within the PPSTI framework, member economies can harness the power of innovation to develop and deploy cutting-edge technologies aimed at reducing emissions across various sectors. This strategic emphasis not only aligns with international climate commitments but also underscores the importance of collaborative efforts in driving the implementation of emission reduction initiatives. Through concerted action within the PPSTI, APEC economies can leverage STI to accelerate the transition towards a low-carbon future, fostering sustainable development and resilience in the face of climate change challenges.

2) It is recommended to draft crucial APEC-wide regulations, standards, and incentives, such as the APEC labeling mechanism, to effectively incentivize energy efficiency measures and sustainable practices across industries. This proactive approach recognizes the significance of establishing common frameworks to guide and promote sustainable practices throughout the APEC region. By implementing labels and common standards, APEC economies can harmonize their efforts towards achieving energy efficiency and sustainability goals. These measures not only enhance transparency and consumer awareness but also provide a level playing field for businesses, encouraging widespread adoption of environmentally friendly practices. Moreover, the implementation of APEC-wide regulations and standards fosters collaboration and knowledge-sharing among member economies, driving innovation and continuous improvement in sustainable practices. Overall, the drafting and implementation of APEC-wide regulations, standards, and incentives serve as foundational steps towards building a more sustainable and resilient future for the region.

3) Establishing APEC market mechanisms for an emissions trading system is a pivotal step towards fostering sustainable development and combating climate change. This initiative aims to create a structured framework that enables the trading of emissions allowances among member economies, thereby incentivizing emissions reductions and promoting the transition to a low-carbon economy. By implementing an emissions trading system (ETS) within APEC, member economies can stimulate innovation in policy frameworks and platforms, fostering collaboration and knowledge-sharing on best practices for emissions reduction. Additionally, the inclusion of mechanisms such as Carbon Border Adjustment Mechanisms (CBAM) ensures the alignment of trade policies with environmental objectives, mitigating carbon leakage and promoting fair competition. This comprehensive approach facilitates effective progress towards achieving net-zero emissions/ carbon neutrality by providing a flexible and market-based mechanism to drive emissions reductions across sectors and borders. Furthermore, the establishment of APEC market mechanisms for emissions trading enhances regional cooperation, supports economic growth, and strengthens resilience to climate change impacts, positioning APEC as a leader in global climate action.

4) Establishing a technology transfer mechanism for green technology within APEC is a strategic recommendation aimed at maximizing the potential of technological innovation and fostering sustainable development across member economies. This

initiative recognizes the critical role of technology in addressing environmental challenges and accelerating the transition to a low-carbon economy. By creating a dedicated mechanism for technology transfer, APEC can facilitate the exchange of valuable knowledge, expertise, and innovations in green technology among its diverse member economies. This collaborative approach enables economies to access and adopt cutting-edge technologies that support their sustainability goals, while also promoting economic growth and competitiveness. Furthermore, the technology transfer mechanism encourages cooperation and partnership-building among stakeholders, including governments, businesses, research institutions, and civil society, to jointly address common environmental challenges. By leveraging the collective expertise and resources of its members, APEC can drive innovation, enhance capacity-building, and promote sustainable development across the region, ultimately contributing to global efforts to combat climate change and achieve a more resilient and prosperous future.

5) Initiating a sharing management platform within APEC, such as a cross-border waste management platform, represents a strategic initiative aimed at fostering collaboration and addressing common environmental challenges across member economies. This platform serves as a hub for sharing technologies, best practices, and expertise related to waste management, enabling economies to adopt sustainable industrial and agricultural processes. By facilitating knowledge sharing and collaboration, the platform enhances the capacity of member economies to manage and reduce waste effectively, mitigating environmental pollution and promoting resource efficiency.

Annex I : Statistical indicator details

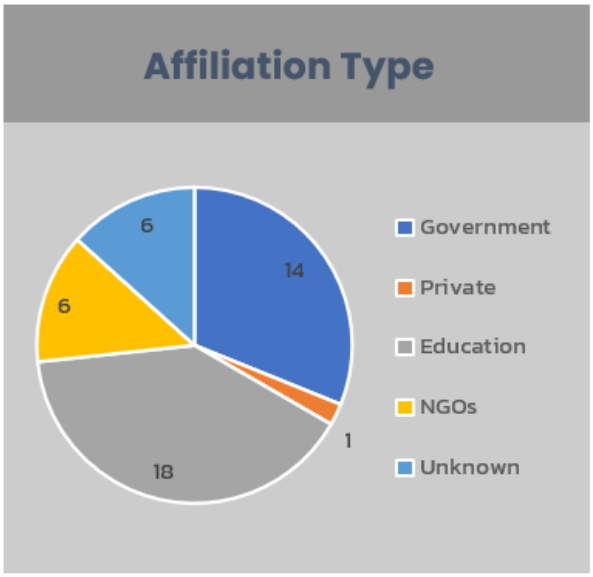
THEME	INDICATOR
Climate	GHG: Total including LUCF ($MtCO_2$-e) GHG: Agriculture ($MtCO_2$-e) GHG: Bunker Fuels ($MtCO_2$-e) GHG: Energy ($MtCO_2$-e) GHG: Energy - Building ($MtCO_2$-e) GHG: Energy - Electricity/Heat ($MtCO_2$-e) GHG: Energy - Fugitive Emissions ($MtCO_2$-e) GHG: Energy - Manufacturing/Construction ($MtCO_2$-e) GHG: Energy - Other Fuel Combustion ($MtCO_2$-e) GHG: Energy - Transportation ($MtCO_2$-e) GHG: Industrial Processes ($MtCO_2$-e) GHG: Land-Use Change and Forestry ($MtCO_2$-e) GHG: Waste ($MtCO_2$-e)
Demography	Population (thousand person) Population growth (annual %) Age dependency ratio, old (% of working-age population) Age dependency ratio, young (% of working-age population)
Economic	GDP (constant 2015 USD, billion) GDP growth (annual %) GDP per capita (constant 2015 USD) GDP per capita growth (annual %) Value added: Agriculture, forestry, and fishing (% of GDP) Value added: Agriculture, forestry, and fishing (annual % growth) Value added: Manufacturing industry and construction (% of GDP) Value added: Manufacturing industry and construction (annual % growth) Value added: Services (% of GDP) Value added: Services (annual % growth) Investment (% of GDP)
Energy	Energy use (kg of oil equivalent per capita) Energy intensity (kg of oil equivalent per 2017 PPP USD1,000 GDP) Electric power consumption (kWh per capita) Access to electricity (% of population) Access to clean fuels and technologies for cooking (% of population) Fossil fuel energy (% of total energy use) Combustible renewables and waste (% of total energy) Non-combustible renewable and nuclear energy (% of total energy use) Electricity production: Coal sources (% of total) Electricity production: Oil sources (% of total) Electricity production: Natural gas sources (% of total) Electricity production: Hydroelectric sources (% of total) Electricity production: Non-hydroelectric renewable sources (% of total) Electricity production: Nuclear sources (% of total) Energy imports, net (% of energy use) Electric power transmission and distribution losses (% of output)
Environment	Forest area (% of land area) Arable land (% of land area) Agricultural land (% of land area) Carbon dioxide damage (% of GNI) Particulate emission damage (% of GNI)
Institution	Environmental sustainability rating (1=low to 6=high) Public sector management and institutions rating (1=low to 6=high)

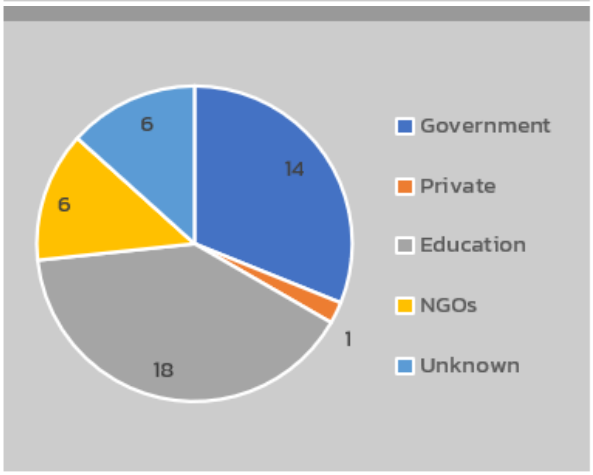
THEME	INDICATOR
	Economic management rating (1=low to 6=high) Business regulatory environment rating (1=low to 6=high) Social inclusion/equity rating (1=low to 6=high) Tax revenue (% of GDP) Central government debt (% of GDP) Public Sector Cash Surplus/Deficit (% of GDP)
Technology	Research and development expenditure (% of GDP) Medium and high-tech manufacturing value added (% manufacturing value added) Medium and high-tech exports (% manufactured exports) High-technology exports (% of manufactured exports)
Tourism	International tourism, receipts (% of total exports) International tourism, expenditures (% of total imports)
Trade	Exports: Goods and Services (% of GDP) Exports: Agricultural raw materials (% of merchandise exports) Exports: Food (% of merchandise exports) Exports: Fuel (% of merchandise exports) Exports: Manufactured goods (% of merchandise exports) Imports: Goods and Services (% of GDP) Imports: Agricultural raw materials (% of merchandise exports) Imports: Food (% of merchandise exports) Imports: Fuel (% of merchandise exports) Imports: Manufactured goods (% of merchandise exports) Tariff rate: All products (%, weighted average) Tariff rate: Primary products (%, weighted average) Tariff rate: Manufactured products (%, weighted average) Trade (% of GDP)

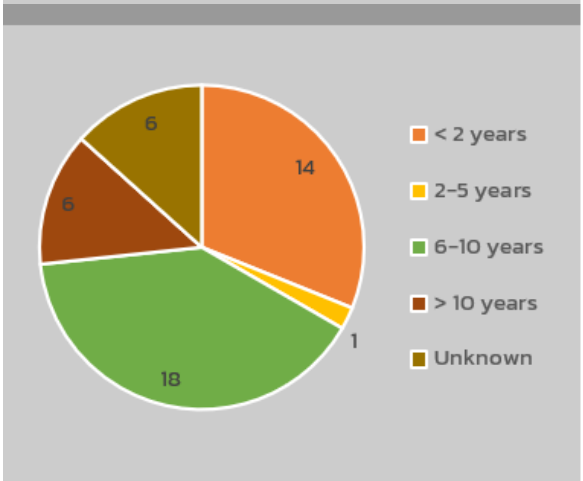
Annex II : Delphi Questionnaires

Total Survey Overview:

- Total Invites: 337
- Total Responses: 45 (13.35% response rate)
- Total Responsive Economies: 16
    - Brunei Darussalam
    - Chile
    - China
    - Indonesia
    - Japan
    - Korea
    - Malaysia
    - Mexico
    - Papua New Guinea
    - Peru
    - The Philippines
    - Russia
    - Chinese Taipei
    - Thailand
    - The United States
    - Viet Nam







Questionnaires
Issue 1 Energy Demand Management
1. On a scale of 1 (Least Effective) to 5 (Most Effective), please rate the effectiveness of the current energy management system in optimizing energy consumption and cost savings within your economy.
2. Based on your justification, please select up to three APEC economies that their energy demand management policies are implemented effectively.
1.1 Energy Efficiency
1. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), Based on your justification, do you agree that the energy efficiency policies within APEC are effectively working towards achieving net zero emissions/ carbon neutrality?
2. On the sectors listed below, please select three sectors based on their prominence of energy efficiency policy towards achieving net zero emissions/ carbon neutrality. a. Energy generation b. Industrial process c. Transportation d. Household e. Building f. Others
3. Which specific energy efficiency measures within APEC demonstrate a strong commitment to advancing net zero emissions/ carbon neutrality? a. Measures for Factory and Building Management and Control b. Building Energy Code (BEC) c. Energy Efficiency Resource Standard (EERS) d. Energy-saving equipment labeling policy e. Promoting energy conservation through supporting investment in upgrading energy-efficient machinery and equipment f. Zero emission vehicles g. Efficient burners h. Others
4. What measures should be integrated into energy efficiency policy to accelerate progress towards achieving net-zero emissions? a. Data analytics and machine learning to optimize energy consumption patterns b. Smart heating and cooling systems c. Building insulation d. Energy-efficient lighting e. Public transport f. Electric vehicles g. Others
5. On a scale of 1 (Least urgent) to 5 (Most urgent), Based on your justification, please indicate the level of urgency for investment in implementing those existing energy efficiency initiatives within APEC towards achieving net zero emissions/ carbon neutrality.
6. Please identify the collaboration among APEC economies regarding energy efficiency are driving progress towards net zero emissions/ carbon neutrality. a. Technology transfer b. Capacity building c. APEC Energy Efficiency Standards d. Cross-Border Energy Trade e. Knowledge sharing f. Others
1.2 Energy Intensity
1. On a scale of 1 (Not confident) to 5 (Very confident), How confident do you perceive the energy intensity policies within APEC as being on track with the net zero emission/ carbon neutrality goals?

Questionnaires
2. What specific energy consumption targets should APEC agree upon for the approaching year 2035, in relation to achieving net zero emissions/ carbon neutrality? a. Reduce energy intensity by at least 45% (Follow the Honolulu declaration, 2011) b. Reduce energy intensity by at least 35% (For post-covid economic growth) c. Reduce energy intensity by at least 30% (if the peak demand reached in 2030) d. Others
3. On the sectors listed below, please select three sectors based on their prominence of energy intensity policy to achieve net zero emissions/ carbon neutrality. a. Industry b. Transport c. Energy production d. Household e. Building f. Trade g. Services h. Tourism i. Others
4. On a scale of 1 (Voluntary) to 5 (Mandatory), how strong should regulations be applied to reduce energy intensity, in alignment with achieving net zero emissions/ carbon neutrality?
5. Based on your justification, which technologies have strong impact on energy intensity, to accelerate progress towards achieving net zero emissions/ carbon neutrality? a. Industry b. Data analytics and machine learning to optimize energy consumption patterns c. Smart heating and cooling systems d. Building insulation e. Energy-efficient lighting f. Public transport g. Electric vehicles h. Others
1.3 Electricity Demand
1. On a scale of 1 (Least concerned) to 5 (Most concerned), how concerned are you on the potential increase in electricity demand as the dominant form of energy in which APEC economies are working towards achieving net zero emissions/ carbon neutrality?
2. On the sectors listed below, please select three sectors based on their important in electricity demand. a. Industry b. Transport c. Energy production d. Household e. Building f. Others
3. Please select the alternative source of electricity which would have the greatest impact on electricity demand in APEC economies to accelerate progress towards achieving net zero emissions/ carbon neutrality? a. Nuclear b. Hydro c. Wind d. Solar e. Others
Issue 2: Energy Transition
1. When are you likely to see the energy supply transition fully take place (i.e., in line with net zero emissions/ carbon neutrality) in APEC?

Questionnaires
a. 2030 b. 2040 c. 2050 d. beyond 2050 e. never
2. On a scale of 1 (Insignificant) to 5 (Highly significant), how significant will the following technologies be in the decarbonization of your economy by 2050? a. Electrification with renewable energies b. Electrification with fossil fuel and CCS c. Electrification with nuclear power d. Fossil-based hydrogen economy and CCS
3. On a scale of 1 (Least) to 5 (Most), how likely will there be an earlier phase-out of fossil fuel infrastructure (i.e., earlier than its economic life) to meet net zero emissions/ carbon neutrality in APEC?
4. Based on your answer in Question 3 (above), and on a scale of 1 (Least) to 5 (Most), how likely would there be tangible impacts of phasing out from fossil fuel infrastructures on small local communities across APEC economies?
2.1 Electricity Supply
1. Based on your justification, please select APEC economies that are most and least responsive to decarbonizing their electricity system towards net zero/ carbon neutrality. a. Most responsive b. Least responsive
2. On a scale of 1 (Not confident) to 5 (Very confident), how confident do you perceive APEC economies to effectively collaborate on cross-border electricity trading towards achieving net zero emissions/ carbon neutrality?
3. On a scale of 1 (Insignificant) to 5 (Highly significant), how desirable is it to achieve a 100% renewable energy target in electricity generation in your economy?
4. On a scale of 1 (Least) to 5 (Most), how significant will the following technologies be in the electricity supply system in your economy to achieve net zero emissions/ carbon neutrality? a. Solar power b. Wind power c. Hydro power d. Nuclear power e. Bioenergy f. Fossil-based electricity with carbon capture and storage g. Lithium battery for electricity storage h. Other chemical electricity storage i. Decentralized prosumer-centric peer-to-peer electricity trading system j. Others
5. Based on your justification, how significant are the following barriers to achieving low carbon electricity systems across APEC economies? a. Intermittency of renewable energy sources b. Insufficient energy storage capacities c. Modernization of grid infrastructure d. Inadequacy of existing infrastructure (i.e., risks of stranded assets) e. Continuation of investments in “old and dirty” technology f. Domestic political constraints (policy and regulation) g. International climate agreements h. Public perceptions about climate change i. Insufficient capital to fund “new and clean” energy projects j. Geopolitics and energy security k. Others

Questionnaires
2.2 Hydrogen Economy
1. Based on your justification, please select up to five APEC economies that have the potential to become major producers/exporters of hydrogen energy.
2. On a scale of 1 (Least) to 5,(Most) how desirable is it to increase the role of hydrogen energy in decarbonizing the hard-to-abate sectors in APEC?
3. On a scale of 1 (Least) to 5,(Most), how confident are you (i.e., what is the probability) of increasing the role of hydrogen energy to decarbonize the hard-to-abate sectors in APEC?
4. On a scale of 1 (Insignificant) to 5 (Highly significant), Based on your justification, how significant are the following barriers to the development of a hydrogen economy across the APEC? a. Hydrogen production costs b. Energy intensity of hydrogen production c. Technical challenges associated with storing and transporting hydrogen d. Establishing a hydrogen infrastructure (production facilities, distribution pipelines, and refueling stations) e. Standardization and safety of a hydrogen economy f. Production of hydrogen from low-carbon or renewable sources g. Domestic political constraints (policy and regulation) h. Public perceptions and acceptance of hydrogen technology i. Insufficient capital to fund hydrogen infrastructure j. Geopolitics and energy security k. Others
Issue 3: Green Economy
3.1 Industrial Processes
1. On a scale of 1 (Very unlikely) to 5,(Very likely), Based on your justification, how likely it is for sustainable manufacturing practices, such as waste reduction and resource efficiency, be adopted for industries in the next decade?
2. Based on your justification, please select three technologies that have the potential to significantly improve industrial efficiency in the green economy. a. IoT (Internet of Things) b. Artificial Intelligence (AI) and Machine Learning c. Renewable Energy Technology d. Energy Storage Systems e. Advanced Robotics f. Advanced Materials g. 3D Printing h. Smart Grids i. Blockchain j. Autonomous Vehicles k. CCS technologies l. Waste-to-Energy m. Recycling and waste management n. Bioenergy and biofuels o. Smart buildings p. Others
3. Which industry sector would be most promisingly adopting green technologies? a. Transportation and Logistics b. Manufacturing c. Agriculture d. Construction and Real Estate e. Pharmaceuticals and Healthcare f. Food and Beverage

Questionnaires
g. Chemicals and Petrochemicals h. Energy Production i. Mining and Resource Extraction j. Textiles and Apparels k. Tourism l. Banking / Finance m. Others
4. Do you agree that the biggest challenge to implementing green industrial processes is initial capital investments?
5. Based on your justification, please select three APEC economies that have effective policies for industrial processes in green economy.
6. Please select three indicators that should be used to evaluate the extent of green economy adoption. a. Energy efficiency b. Resource efficiency c. Emissions reduction d. Waste reduction e. Quality and productivity f. Cost savings g. Supply chain impact h. Innovation and technology adoption i. Health and Wellness j. Social awareness k. Behavior change l. Others
3.2 Agricultural Practices
1. On a scale of 1 (Weak) to 5 (Very strong), how strongly do you believe sustainable agriculture is essential for addressing global food security and environmental challenges?
2. Based on your justification, please select three technologies with the potential to significantly enhance the sustainability of agricultural practices. a. Precision Agriculture b. IoT and Sensors c. Drones and UAVs d. Blockchain e. Vertical Farming f. Aquaponics and Hydroponics g. Biotechnology and Bioengineering h. Robotics and Automation i. Soil Health Monitoring j. Water Management Systems k. Waste-to-energy l. Others
3. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), Based on your justification, do you agree that accessing affordable smart-farming technologies is the challenging factor for small-scale farmers?
4. Please select three APEC economies that have effective policies for agricultural practices towards green economy.
5. Based on your justification, what would likely be the most significant change in agricultural practices towards green economy in the next decade? a. Vertical farming expansion b. Digital farming (adoption of digital technologies e.g. IoT sensors, drones to enhance precision farming practices, optimize resource use and monitor crop health in real-time)

Questionnaires
c. Blockchain-assisted traceability (transparent and traceable supply chains, ensuring food safety and sustainability) d. AI and Machine Learning (for crop prediction, disease detection, resource optimization) e. Urban farming (rooftop gardens and hydroponics for supporting local food production and reduction of food miles) f. Renewable energy integration (use renewable energy sources to reduce carbon emission) g. Biotechnology advances (for crop improvement and disease resistance with responsible use of GMO crops) h. Circular economy approach (reduce waste and promote recycling and reuse in agricultural production system) i. Sustainable Livestock Management (improve livestock practices, including better animal welfare, reduced methane emissions, and sustainable feed sourcing) j. Agroforestry Promotion (enhance integration of agroforestry practices to improve land use efficiency, conserve water, and enhance carbon sequestration) k. Others
3.3 Waste Management
1. On a scale of 1 (Least Effective) to 5 (Most Effective), please rate the effectiveness of waste management policies within your economy.
2. Based on your justification, please select three APEC economies that have effective waste-management policies.
3. From the choices below, please select five sources of waste in terms of environmental impact urgency in APEC economies. a. Packaging and packaging waste b. Construction and demolition waste c. Waste Electrical and Electronic Equipment (WEEE) d. Hazardous waste e. Biodegradable waste f. Food waste g. Agriculture h. Municipal solid waste i. Industrial waste j. Biomedical waste k. Chemical waste l. Others
4. Which specific waste-management targets should APEC agree upon for the approaching year 2050 to achieve net-zero emissions?
5. On a scale of 1 (Not at all important) to 5 (Very important), To what extent do you believe the collaboration among APEC economies regarding waste management are driving progress towards net-zero emissions? a. Technology transfer b. Capacity building c. APEC Waste Management Targets d. Collaborative R&D e. Financial instruments f. Others
3.4 Green Tourism
1. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), how strongly do you agree that green tourism plays an important role towards net zero emissions/ carbon neutrality?
2. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), how strongly do you agree that well-managed tourist attractions in their natural state play a vital role in promoting green tourism?

Questionnaires
3. Which areas would be most prominently adopted for green tourism to achieve net zero emissions/ carbon neutrality? Please select three choices and provide reasons briefly. a. Logistics management b. Energy management c. Water management d. Waste management e. Food and Agriculture f. Infrastructure g. Others
4. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), Do you agree that local communities would benefit from green tourism?
5. On a scale of 1 (Significantly decrease) to 5 (Significantly increase), How would the demand for green tourism in your economy change by 2050?
6. On a scale of 1 (Least Effective) to 5 (Most Effective), please rate the effectiveness of green tourism policies in your economy.
7. Based on your justification, please select three APEC economies that have effective green tourism policies.
8. Please select five areas of development in green tourism that require immediate measures in your economy. a. Resource management b. Educate and engage locals c. Educate and engage tourists d. Awareness of cultural and social contexts e. Geographic information systems f. Public involvement g. Preservation of heritage sites h. Hospitality management i. Landscape architecture j. Community planning/transportation k. Others
9. On a scale of 1 (Not at all important) to 5 (Very important), To what extent do you believe the collaboration among APEC economies regarding green tourism are driving progress towards net zero emissions/ carbon neutrality? a. Technology transfer b. Capacity building c. Knowledge sharing d. Collaborative R&D e. Financial instruments f. Others
Issue 4: Carbon Emission Sinks
4.1 Carbon Capture, Utilization and Storage (CCUS)
1. Based on your justification, please select three APEC economies that have effective CCUS policies.
2. What part of the CCUS processes require urgent technological development or breakthrough? (select at least one choice) a. Capture b. Transportation c. Storage d. Utilization
3. On a scale of 1 (Low) to 5 (High), please rate the severity of the following bottlenecks for Carbon Capture and Storage (CCS) deployment in APEC. a. Policy b. Regulation

Questionnaires
c. Investment d. Infrastructure e. Technology f. Manpower g. Safety concerns h. Public perception i. Others
4. On a scale of 1 (Not at all important) to 5 (Very important), To what extent do you believe the collaboration among APEC economies regarding CCS are driving progress towards net zero emissions/ carbon neutrality? a. CCS Infrastructure sharing b. Knowledge sharing c. Technology transfer d. Capacity building e. R&D collaboration f. Others
5. Based on your justification, when do you expect CCS to play a critical role in achieving net zero emissions/ carbon neutrality in APEC? a. by 2030 b. by 2040 c. by 2050 d. beyond 2050 e. never
6. On a scale of 1 (Low) to 5 (High), please rate the following collaborations that your economy requires from APEC economies, to successfully implement CCS. a. Financial support b. CCS Infrastructure sharing c. Knowledge sharing d. Technology transfer e. Capacity building f. R&D collaboration g. Others
7. On a scale of 1 (Low) to 5 (High), please rate the severity of the following bottlenecks for Carbon Capture and Utilization (CCU) deployment in APEC a. Policy b. Regulation c. Investment d. Incentives e. Market demands f. Technology g. Manpower h. Safety concerns i. Others
8. On a scale of 1 (Not at all important) to 5 (Very important), To what extent do you believe the collaboration among APEC economies regarding CCU are driving progress towards net zero emissions/ carbon neutrality? a. Market opportunities within APEC b. Knowledge sharing c. Technology transfer d. Capacity building e. R&D collaboration f. Others

Questionnaires
9. On a scale of 1 (Low) to 5 (High), please rate the following collaborations that your economy requires from APEC economies to successfully implement CCU. a. Market opportunities within APEC b. Knowledge sharing c. Technology transfer d. Capacity building e. Joint R&D f. Others
4.2 Land-use Practices
1. Based on your justification, please select three APEC economies that have effective land-use policies for net zero emissions/ carbon neutrality.
2. On a scale of 1 (Least Effective) to 5 (Most Effective), please rate the effectiveness of land-use practices for net zero emissions/ carbon neutrality in APEC. a. Reforestation b. Afforestation c. Agroforestry d. Carbon farming e. Others
3. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), Based on your justification, do you agree that forest carbon credits should be included in an Emission Trading Scheme (ETS) to accelerate reforestation and afforestation?
4. On a scale of 1 (Strongly disagree) to 5 (Strongly agree), Based on your justification, do you agree that a payment scheme for public goods and services, such as those related to climate mitigation and biodiversity, is a key policy instrument for supporting agroforestry?
5. On a scale of 1 (Low) to 5 (High), please rate the severity of the following bottlenecks for implementing carbon farming in APEC. a. Policy b. Farmer adoption c. Incentives d. Carbon market e. Knowledge f. Managerial abilities g. Technology h. Others
6. On a scale of 1 (Not at all important) to 5 (Very important), To what extent do you believe the collaboration among APEC economies regarding land-use practices are driving progress towards net zero emissions/ carbon neutrality? a. Carbon trade within APEC b. Knowledge sharing c. Technology transfer d. Capacity building e. R&D collaboration f. Others
7. On a scale of 1 (Not at all important) to 5 (Very important), please rate how much your economy would require the following collaborations from other APEC economies to effectively implement land-use practices for achieving net zero emissions/ carbon neutrality. a. Carbon trade within APEC b. Capacity building c. Technology transfer d. R&D collaboration e. Others
Issue 5: Offset Policies

Questionnaires
5.1 Clean Development Mechanism (CDM)
1. On a scale of 1 (Not Significant) to 5(Most significant), please rate the level of significance of the CDM implementation in progressing towards achieving net zero emissions/ carbon neutrality.
2. Based on your justification, please select three APEC economies that their emission trading scheme (ETS) are implemented effectively.
3. Based on your justification, please select three APEC economies that their Renewable Energy Certificates (RECs) are implemented effectively.
4. On a scale of 1 (Not urgent) to 5 (Extremely urgent), please indicate the level of urgency for the establishment of APEC standards, particularly ETS and REC to achieve net zero emissions/ carbon neutrality.
5. To what extent do you believe the collaboration amongst APEC economies needed regarding CDM are driving progress towards net zero emissions/ carbon neutrality? a. APEC Measurement and verification standards b. APEC carbon price c. Revenue recycling scheme d. Capacity building e. Knowledge sharing f. Others
5.2 Cross Border Adjustment Mechanism (CBAM)
1. At what level would CBAM affect APEC economies when it comes to full implementation? a. The export of most products entirely stops. b. The export of some products entirely stops. c. Most product exports diminish significantly. d. Some product exports diminish significantly. e. Most product exports decrease slightly. f. Some product exports decrease slightly. g. Most product exports return to normal.
2. Based on your justification, which industry would be most affected by CBAM? (Select one) a. Cement b. Fertilizers c. Petroleum d. Petrochemicals e. Adipic Acid f. Iron and Steel g. Aluminum h. Hydrogen i. Glass j. Pulp and Paper k. Ethanol l. Electricity m. Other
3. Based on your justification, which APEC economy has the most effective policies in response to CBAM?
4. Based on your justification, which economy outside APEC has the most effective policies in response to CBAM?
5. On a scale of 1 (Least likely) to 5 (Most likely), Based on your justification, what is the likelihood that CBAM will lead to global carbon market?

Annex III : List of Project steering committee

No.	Title	Name	Economy	Position
1	Dr	Nares Damrongchai	Thailand	Chairman
2	Dr	Surachai Sathitkunarat	Thailand	Vice Chairman
3	Dr	Byeong Won Park	Republic of Korea	Committee
4	Dr	Rafiq Dossani	The United States	Committee
5	Mr	Imran Arshad	Canada	Committee
6	Mr	Simon Robertson	Canada	Committee
7	Dr	Jet P. H. Shu	Chinese Taipei	Committee
8	Dr	Tan Shu Ying	Malaysia	Committee
9	Dr	Kommate Jitvanichphaibool	Thailand	Committee and Secretary
10	Dr	Titima Songkroh	Thailand	Committee and Assistant Secretary

Annex IV : List of Project working group

No.	Title	Name	Position
1	Dr	Kitipong Promwong	Executive Advisor of APEC CTF
2	Dr	Surachai Sathitkunarat	Chairman
3	Dr	Kommate Jitvanichphaibool	Vice Chairman
4	Dr	Suchat Udomsopagit	Member
5	Dr	Srichattra Chaivongvilan	Member
6	Dr	Apichat Aphaiwong	Member
7	Dr	Wasutadon Nakawiroj	Member
8	Mr	Phira Chaochaloemphong	Member
9	Dr	Titima Songkroh	Member and Secretary