Recommendations for Driving Trade & Investment for DC Power Systems and Microgrid Frameworks Through Public Policy Alignment

APEC Energy Working Group

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Asia-Pacific Economic Cooperation

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INTRODUCTION

Governments and private sector entities across the APEC region are experiencing growing demand for electricity coupled with the need to build more resilient and low-cost energy infrastructures.[1] Both developed and developing economies wish to improve the reliability of services while extending safe, low-carbon electrification to previously unserved and remote communities. At the center of these efforts is the rapid proliferation of distributed energy resources (DERs), which are small-scale energy resources usually situated near sites of electricity use.[2] DERs – which include electric vehicles, battery storage, fuel cells, rooftop solar, wind generation, and more – are changing how electricity is traded, delivered, and consumed.

Technological, market, and regulatory barriers can impede investment in such energy systems. This requires governments and regulators to review policies affecting energy system development, deployment, and integration across a broad range of cases.

This project takes a long-term view towards enabling APEC economies' energy and economic resiliency by focusing on two technology systems essential to meeting economies' objectives: **DC power and microgrids**. The project has two primary goals. First, it seeks to build regulatory capacity in APEC economies that promotes the use of efficient, resilient, and safe technologies towards the achievement of climate-related objectives. Second, it aims to facilitate trade and investment of technologies critical to the energy transition through the promotion of aligned regulatory and conformity assessment approaches.

The project builds upon the work of prior APEC projects that assessed the benefits of leveraging these systems, demonstrating their high value, particularly for rural areas of developing APEC members (e.g., EWG 15 2011A, EWG 06 2013A, EWG 04 2023S). They deliver resilient, low-carbon energy services to isolated areas with greater reliability and at lower costs than traditional systems.

This report outlines recommendations based on the learnings of prior projects and a workshop hosted at the First Senior Officials Meeting in 2025. The workshop convened 66 public and private sector experts from Canada; Chile; People's Republic of China; Hong Kong, China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; Papua New Guinea; Peru; the Philippines; Chinese Taipei; Thailand; United States; Viet Nam, and the World Trade Organization (WTO). The agenda and information on workshop participation are found in Annex II; presentation materials are in Annex III.

After summarizing the project's key findings, this report has three main segments. First, it will cover applications of DC power and microgrids to educate economies on their potential upsides and drawbacks. Second, it will review the challenges the public and private sectors face in enabling their investment. Third, it will outline recommendations for overcoming those challenges.

[1] According to the APEC Energy Demand and Supply Outlook (7th Edition), produced by the Asia Pacific Energy Research Centre, the final energy demand of APEC economies by 2050 will increase by 21 percent above 2016 levels.
[2] Unlocking the Potential of Distributed Energy Resources – Analysis - IEA

KEY FINDINGS AND RECOMMENDATIONS

FINDINGS:

New challenges require transformative approaches:

A. Deploying more DERs and renewable energy sources comes with its challenges. This includes long-range transmission, grid reliability, and remote distribution issues. DC power can help overcome these obstacles, particularly when combined with microgrids.

Meeting Growing Energy Demand:

B. Microgrids and the use of DC power have profound potential to meet growing energy demand in developed and developing economies. This is especially true given the AI boom and rapid increase in demand for data centers.
C. Microgrids and DC power demonstrate important operational flexibility, from electrifying remote areas with underserved populations to supporting dense, urban environments.

Achieving governments' developmental and climate objectives:

D. In addition to official APEC objectives, many member economies have individual, domestic commitments to expand energy access, modernize grids, improve grid reliability and efficiency, increase the share of renewable energy sources, and accelerate decarbonization. Microgrids and DC power are well-suited to support these efforts.

Improving investment viability and facilitating trade:

E. Safety and security of energy infrastructure are paramount concerns for businesses and governments as they consider such investments. If investments are not safe or secure, they are not viable in the long run and can endanger consumers.
F. Both demand-side and technological barriers limit DC power deployment. Compared to AC systems, these include relatively less demand for DC products due to limited everyday applications, higher costs, and limited engineering expertise.
G. Significant regulatory barriers to operationalizing these investments exist, including a lack of international regulatory alignment, the absence of domestic technical regulations, little inter-agency coordination, enforcement challenges, and complex permitting processes.
H. Regulatory barriers are directly tied to trade flows in climate technologies, especially given the complex global supply chains for these products and their components.

POLICY RECOMMENDATIONS:

The following represents a synthesized version of the project's policy recommendations. See Section 3 for additional details.

Enabling technological advancement and deployment:

A. Facilitate public-private partnerships focused on DC power technologies and microgrids, encouraging local public and private sector participation.
B. Promote the use of smart technologies and support academic programs to study and develop DC power and microgrid applications.

Overcoming market challenges to investment:

A. Launch formal programs to improve DC power and microgrids expertise among engineers, technicians, operators, and consumers. Economies are encouraged to promote women's leadership and participation opportunities as part of this process.
B. Share case studies – including successes and failures – of other economies' investments in applications of these technologies.
C. Promote the development of official key performance indicators (KPIs) at a regional level.
D. Provide financial incentives to investors that help mitigate investment risks, especially for remote infrastructure.

Cultivating flexible regulatory frameworks while maintaining safety and security:

A. Adopt international best practices for regulatory frameworks in alignment with World Trade Organization principles and requirements on technical barriers to trade.
B. Develop and implement comprehensive, tailored policies for creating new markets for DERs, DC power use, and microgrids deployment.
C. Streamline existing grid-related policies and permitting procedures – especially given the connectivity of DC and AC applications.
D. Explore regulatory "sandbox models" for DC power and microgrid pilot projects.
E. Adopt best practices to improve inter-agency coordination and stability in the regulatory environment
F. Adopt formal programs to improve workforce expertise on DC power and microgrids. This includes encouraging formal roles for women's leadership and participation.

I. APPLICATIONS & RISK MITIGATION

Electric power grids across the world generally generate energy from a central hub and distribute it through transmission lines to customers. These grids overwhelmingly operate on alternating current (AC) power, the typical form of electricity in homes and businesses. In recent years, grid systems have become increasingly decentralized, with the introduction of distributed energy resources (DERs) and greater use of direct current (DC) power – though DC power use is still rather limited. Advancements in technology, along with the need to improve the resiliency of and access to power, are contributing to a rapid proliferation of microgrids, DERs, and DC power connecting them. The following sections will provide an overview of the primary applications and opportunities for DC power and microgrids, preceded by a review of common risk mitigation issues.

Today, in developing economies, microgrids and DC power are primarily used to electrify and provide 24/7 service to remote areas, underserved communities, and islands. This includes households, agriculture, research centers, and more. In developed economies, these resources largely focus on meeting growing energy demand, transitioning to cleaner energy sources, and improving the reliability and resiliency of services for public and private facilities. However, these use-cases apply across the entire range of economies' development statuses.

RISK MITIGATION OF DC POWER AND MICROGRID APPLICATIONS

Governments and the private sector alike must prioritize risk mitigation in designing and applying these technologies. There are five foundational areas for addressing this risk:

1. ***Safety***: This is paramount in achieving reliable power delivery to users. This applies not only to users but also to operators, installers, and technicians. Safety issues can arise in various circumstances, from equipment failure, human error, and malfunctions.
2. ***Security***: Security is critical to increasing investment protections from issues like intentional destruction and cyberattacks.
3. ***Sustainability***: Investments have the best return on investment when they are designed and deployed to work in the long term. Sustainable design enables reliable operation from reliable energy sources, including renewables.
4. ***Cost-effectiveness***: From a financial standpoint, cost-efficiency metrics strive to create the best possible energy production and consumption scenarios.
5. ***Performance***: An investment should be able to deliver the necessary power during normal operating parameters and outlier events like natural disasters. Performance support – including system modeling, simulation, and planning – strives to provide as much power as possible, even during critical events.

The recommendations section of the report will outline how to address these issues while overcoming barriers to trade and investment.

DC POWER

Deploying more DERs and renewable energy sources comes with challenges – including long-range transmission, grid reliability, and remote distribution issues. DC power can help overcome these obstacles. This section covers four types of DC applications, largely centered on grid cases.

Line-Commutated Converter (LCC) – High Voltage Direct Current (HVDC)

Large-scale renewables tend to be far from load centers (e.g., wind turbines located outside an urban center). This makes long-distance transmission essential to increasing an economy's renewable generation capacity. However, long-distance transmission is challenging. LCC-HVDC can be applied to efficiently conduct long-distance power transmission, connecting DERs to AC grids. This type of technology has a high degree of application maturity and low construction costs. However, the operational flexibility of these systems is low. LCC-HVDC has been used in many projects. For example, the People's Republic of China has 18 operational LCC-UHVDC projects, with the maximum transmission capacity around 12GW and the longest transmission distance exceeding 3300km.

Voltage Source Converter (VSC)-DC

Photovoltaic (PV) resources generate their power as DC, and batteries store and emit DC. As such, these resources typically need an inverter to convert DC to AC, which is generally used in homes and businesses.[3] VSC-DC technology enables rapid and independent control of operational power and voltage. It is often used in the transmission of both onshore and offshore renewable power sources. It is also progressively being applied to support flexible interconnection between AC grids, interconnecting different power supply areas. This is especially important when addressing the large-scale integration of distributed PV resources into AC distribution networks. In this application, VSC-DC allows surplus PV power to be transferred directly to between different areas, while preventing reverse power flow from the distribution network to the transmission grid. VSC-DC has moderately high application maturity and operational flexibility. However, the cost of VSC-DC projects is moderately high.

Medium Voltage DC (MVDC) and HVDC Grids

HVDC grids connect multiple converter stations into a network using VSC-DC technology. This improves the system's operational flexibility by allowing for dynamic adjustments of network topologies. HCVDC grids have moderate application maturity and high operational flexibility. However, they have high construction costs and have challenges associated with dispatching, control, and protection strategies.

An MVDC grid integrates various power sources into a centralized hub with a high degree of operational flexibility. It is modular and scalable, promoting stable power system operation.

[3] https://www.nrel.gov/docs/fy19osti/72102.pdf

MICROGRIDS

A microgrid is a group of interconnected loads and DERs that acts as a single controllable entity with respect to the grid.[4] Microgrids provide localized power generation, which is useful for enhancing energy security and resilience. They are typically designed to either separate from the grid (e.g., during a destabilizing incident) or operate entirely separately from a grid. In either case, they can be helpful for economies vulnerable to natural disasters or other such incidents.

APEC economies are turning toward microgrids as an important tool to meet rising energy demand, integrate more renewables, and efficiently couple energy sectors. Both utilities and "behind-the-meter" actors (e.g., business parks, campuses or communities) use microgrids. For example, the Republic of Korea uses microgrids to support renewable energy integration, energy storage system deployment, and EV grid connectivity. Korea's renewable energy share is 7%, 75% of which is small-sized.

DC power can be extremely effective when used in a microgrid framework. By connecting DERs directly through DC power, one avoids AC-DC conversion losses while enabling flexible power flow distribution, smooth connection and disconnection with grids, and system black starts. This section covers four important microgrid use-cases, including those with DC power.

Connected Utility Microgrids

Microgrids can provide utilities with increased flexibility and stability when operating under a wider grid. They can do this in several ways. First, they can balance power supply and demand by reducing demand in peak periods and storing energy during low-demand periods. This practice is known as peak shaving and valley filling. Second, they can stabilize power fluctuations through smart grid technologies, inverters, and energy storage systems. Third, microgrids can "black start." This is the ability to restart and provide power using its own resources, even when the main grid is down.

Behind-the-Meter Microgrids

'Behind-the-meter' (BTM) microgrids operate on the customer's side of the electric meter, providing power directly to an end-user. They can also export power to the main grid if allowed by the utility. Such setups typically include power generation, transmission, and energy storage systems. BTM microgrids are not only deployed in community-wide settings but also increasingly in diverse commercial environments. This includes servicing cloud services and technology centers, consumer retail locations, telecommunication hubs, manufacturing facilities, and more.

Remote Microgrids

Microgrids have a unique capacity to provide electricity in remote environments. With increasingly congested metro centers, microgrids are also being used in isolated settings for new investment projects that require a lot of energy – like data centers. While remote

[4] https://www2.nrel.gov/grid/microgrids#:~:text=A%20microgrid%20is%20a%20group,grid%2Dconnected%20or%20island%20mode.

microgrids have a historical reliance on diesel, they are becoming increasingly popular due to the greater availability and lower cost of PV and energy storage technologies.

Chile, for example, has isolated systems (smaller than 1.5 MW) in 11 of 16 regions, which are operated by both distribution companies and local users. Of those, companies have 30 systems with an average of 200 users; local users have 23 systems with an average of 140 users as well as 50 systems with an average of 12 users. In total, there are more than 100 isolated systems in Chile serving around 10,000 users.

Lessons learned from remote power systems are thoroughly researched and explained in the APEC EWG 04 2021A project report.[5]

Academic Microgrids

Academic institutions have proven useful in inventing, deploying, and studying nascent technologies. Due to the nature of work being conducted on academic campuses, they are particularly valuable cases of AC and DC microgrids deployment. These institutions often conduct long-term scientific experiments or operate health care facilities that require constant energy and protection from grid disturbances. In such settings, microgrids can also be used to meet sustainability goals. For example, Bloom Energy partnered with the California Institute of Technology to deploy an advanced microgrid in Pasadena, California that resulted in reductions of downtime, CO2, and water consumption. In Thailand, the Chiang Mai Rajabhat University's Asian Development College for Community Economy and Technology (adiCET) uses a DC microgrid as a living laboratory. adiCET uses this DC microgrid to evaluate low-cost, low-voltage DC community smart power systems. This includes modifying and studying household appliances for DC and AC usage.

[5] https://www.apec.org/publications/2023/05/lessons-learned-on-resiliency-and-uptake-of-variable-energy-resources-from-islanded-grids-that-support-apec-clean-energy-goals

II. CHALLENGES: MOBILIZING INVESTMENT AND TRADE

Despite clear advantages presented by DC power and microgrid applications, there are significant barriers to mobilizing their investment and facilitating trade in their products. Those challenges can broadly be grouped into three buckets: technological, market, and regulatory. Project participants recognized that many challenges will be cross-cutting, affected by factors in multiple buckets. However, grouping these issues helps identify targeted policy recommendations for members.

TECHNOLOGICAL CHALLENGES

AC and DC have both been used since the dawn of electricity. However, existing AC systems are large in scale, technologically mature, and equipped with widely used, reliable devices. DC power has limitations due to lack of existing infrastructure and utilization maturity. There are differences in maturity levels depending on the case, as noted in the above section on DC power applications. For example, in grid settings, LCC-HCVC deployment is highly advanced, whereas VSC-DC and HVDC are slightly less so. This makes AC/DC hybrid systems an important application for economies' growth priorities. As discussed in the below section, there are very few household consumer goods that rely solely on DC power.

Microgrids, which can be AC or DC, have proven to be reliable and flexible systems. This is in part because of their status as localized grids but also because of the quick proliferation of low-cost DERs and microgrid components.

MARKET CHALLENGES

Despite recent advancements, there remain high barriers to market entry. This is in part due to the high costs of some of these technologies, limited local expertise, and lower consumer demand for some applications.

With most grid systems in APEC economies operating on AC power, this makes familiarity with AC systems more prevalent and spare parts for all AC uses more readily available. This feedback loop is perpetuated by ubiquitous supply chains for AC products. Conversely, there are only a small number of household consumer goods that operate on DC power. As such, relative prices of DC power products are high and demand for DC products is low. Once deployed, spare parts are not as readily available in remote settings, and technicians are less familiar with DC power. This makes service costs even higher. Generating a large supply of low-cost DC products will be essential to widespread uptake of the technology at a household level. Moreover, the general lack of standardized designs for microgrids requires most microgrids to be designed from the ground up, adding costs.

Many of these dynamics are exacerbated when DC microgrids are deployed in remote settings. Such investments are less attractive for distribution companies because they tend to have higher risk, lower profit margins, and lower demand. Due to geographical challenges, they also are associated with long replacement times and reputational risks. Small-scale electricity distribution providers tend to see the operation of isolated systems as risky due to a lack of experience and financial support. Despite their potential, a case study

of remote grid applications in Chile revealed no company has applied for a formal concession to build a new or operate an existing isolated electric system (DC or AC) in the last 40 years.

REGULATORY CHALLENGES

Regulatory barriers are directly tied to trade flows in climate technologies, especially given global, complex supply chains for these products and their components.[6] Investment and trade in DC power and microgrid systems are inhibited by the global non-alignment and domestic absence of policies, regulations, and established processes for their application and operation. This global non-alignment includes limited local use of existing international standards (e.g., UL 1741 – Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources). There is difficulty aligning and coordinating complex policies among domestic agencies, providers, and levels of government (e.g., state versus federal). In some economies, enforcement of existing policies can be a challenge. These dynamics can be worsened by frequent changes in regulatory agency leadership, resulting in inconsistent policy and volatile cost structures.

As a system, microgrids can lack the sorts of regulations to which larger AC grids are subject. If a microgrid is ahead of the meter and connected to a regulated utility, those regulations generally extend to the microgrid and its components. However, if a microgrid is behind the meter, it may not be regulated in the same way. Its components may be subject to product-specific technical regulations, but the microgrid as a system may not be.

Breaking a microgrid down into its parts, including DERs, there are significant gaps in regulatory frameworks (*see Call Out Box*) for those components. This poses significant safety risks for consumers and microgrid operators. Approaches to technical requirements to those products and their components – and how they interact with one another – are varied across jurisdictions and between economies. This complicates investment and raises trade barriers as supply chains of the products and their components are spread across many economies. Accelerated lifecycles of these products and their components also mean they are pushed onto the market at faster and faster rates. This poses challenges to regulatory systems which seek to both enable that innovation while protecting consumers.

[6] According to the WTO | World Trade Report 2022 Climate change and international trade, while tariffs on environmental goods are on average lower compared to tariffs for other goods, environmental goods are particularly affected by non-tariff measures (NTMs). Technical barriers to trade (TBT) are especially important to environmental goods – like solar panels and wind turbines – as they are often subject to technical regulations and conformity assessment procedures. Between 2005 and 2020, TBT-related specific trade concerns (STCs) in the WTO TBT Committee covered an annual average of USD42 billion in imports of environmental goods.

Elements of Regulatory Frameworks

Regulatory frameworks simultaneously seek to protect consumers, facilitate trade, and drive innovation. There are four primary components of regulatory frameworks:

A. **Standards and technical requirements**: The written minimum requirements applicable to a given product or service to be used to verify compliance and perform conformity assessment. Standards serve as the foundation of an effective regulatory framework. Their selection often includes an assessment of the parties involved in their development (optimally a diverse set of stakeholders), their development methodologies (optimally consensus-based), the geographic region they apply to, and whether compliance is voluntary or mandatory.
B. **Conformity assessment:** The process used to verify compliance with standards, schemes, regulations and other specifications. This includes evaluation, testing, inspection, validation, verification, certification, and accreditation. Conformity assessment is generally performed by either first, second or third parties, depending on the system and a determination of the level of risk. *Standards alone cannot drive value or impact without conformity assessment, and conformity assessment cannot be performed without technical requirements.*
C. **Confidence building and accreditation:** A mechanism to assess and assure competence of the conformity assessment providers and method; accreditation is third-party attestation related to a conformity assessment body, conveying a formal demonstration of its competence, impartiality and consistent operation in performing specific conformity assessment activities. At a minimum, most regulatory frameworks consider bodies to whom they can entrust the accreditation function, and determine which conformity assessment activities require such accreditation.
D. **Surveillance:** The systematic iteration of conformity assessment activities as a basis for maintaining the validity of the statement of conformity; this can be pre-market testing or inspection, or post-market surveillance. Even when operating in good faith, products that find their way to market can be found to be in noncompliance with applicable regulations or standards. Surveillance is required to identify and remove noncompliant products and services.

To balance regulatory objectives and priorities, governments often take different approaches in developing a regulatory framework, assembling the four essential elements in unique combinations. There is no one single formula that is applicable in every circumstance. Each has their merits and reflects the realities of their economies and systems of governance.

III. RECOMMENDATIONS: INVESTMENT LONGEVITY, SAFETY, AND SECURITY

Workshop participants participated in hands-on breakout sessions to consolidate key findings and recommendations for APEC member economies. The following proposals reflect the consensus of those discussions among the public and private sectors at a critical moment in APEC economies' electrification journeys.

OVERCOMING TECHNOLOGICAL CHALLENGES

As DC power technologies naturally become more prevalent over the coming years, there are three primary ways for APEC members to accelerate and incentivize that deployment.

1. Facilitate public-private partnerships focused on DC power technologies and microgrids. This includes participation in global standardization efforts for applications of DC power in varied scenarios. Local public and private stakeholder participation in standards technical committees are critical to effective, consensus-based standards development.
2. Promote the use of smart technologies and AI to advance the digital and intelligent transformation of power systems. This includes using smart inverters and digital modeling to forecast and avoid grid challenges.
3. Enable innovation by supporting academic programs that study and develop DC and microgrid applications. Academia is a powerful setting for breaking frontiers in technological maturity.

OVERCOMING MARKET CHALLENGES

APEC economies can take several concrete steps to address market barriers to investment.

1. Improve DC power and microgrids expertise among engineers, technicians, operators, and consumers. This may take the form of formal training programs and awareness campaigns. Economies are encouraged to promote women's leadership and participation opportunities as part of this process – including through formal documentation and metrics.
2. Share cases studies – including successes and failures – of other economies' investments in applications of these technologies. This increases the awareness of these applications' potential to address common goals and challenges, as well as any learnings.
3. Promote the development of official key performance indicators (KPIs) for DC power and microgrid use at a regional level. These KPIs enable better return on investment (ROI) forecasting and uptake of electrification plans by private investors. It is critical that KPIs are compatible between economies, so they don't create new investment barriers.
4. Provide financial incentives to investors that help mitigate investment risks, especially for remote infrastructure. Such incentives may include, for example, tax deductions for donated DC systems.
5. Strengthen public-private partnerships, which can stabilize costs related to investment.

OVERCOMING REGULATORY CHALLENGES

Regulatory frameworks play an outsized role in hampering or facilitating investment. This section's proposals are in two parts. First, the workshop recommends foundational best practices that protect consumers, facilitate trade, and drive innovation across all sectors. Second, the project lists sector-specific regulatory proposals based on workshop case studies.

Best Practices

A. **Standards**: As outlined under the WTO Technical Barriers to Trade (TBT) Agreement, economies should leverage international standards[7] as the basis of technical regulations or conformity assessment procedures, wherever applicable and appropriate. This is key to greater regulatory alignment and reducing barriers to trade.
B. **Technical regulations:** Economies should periodically review technical regulations and conformity assessment procedures to examine increasing alignment with relevant international standards and any new developments therein.
C. **Conformity assessment:** It is important to recognize that conformity assessment approaches are not one-size-fits-all. Regulators have the flexibility to choose and should regularly review the appropriate method of demonstrating conformity according to their policy objectives, market characteristics, risk assessment and confidence needs.[8] The conformity assessment development process is about appropriately identifying, analyzing, evaluating, and managing risk efficiently and effectively while facilitating trade in line with international obligations. Regulators should assess the risks to public health, safety, security, the environment and privacy, as well as the impact noncompliance would have on society at large.
D. **Confidence building and accreditation:** Economies can promote confidence by establishing a clear set of requirements from which the conformity assessment providers will be selected and allow applications from organizations independent of their geographical location. This will allow the largest pool of providers to offer services and enable the marketplace to allocate resources more efficiently.
E. **Surveillance:** It is common for an economy to undertake several surveillance methods concurrently. This improves effectiveness while preserving enough flexibility to cover the variety of circumstances where noncompliance might be identified.

When implemented, these best practices are designed to address many of the specific issues identified above by allowing flexibility to support innovation while also protecting consumers. This is especially important given the DC power and microgrids' accelerated product lifecycles, global supply chains, and pronounced safety issues.

[7] International standards as defined in the WTO TBT Committee Decision on International Standards: https://www.wto.org/english/tratop_e/tbt_e/principles_standards_tbt_e.htm
[8] WTO TBT Committee Guidelines on Conformity Assessment: https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/G/TBT/54.pdf&Open=True

Regulations for DC Power and Microgrids

For use in alignment with international best practices, workshop participants identified the following sector-specific recommendations:

1. Given the relative lack of regulations for these technologies, economies should seek to develop and implement comprehensive, tailored policies for creating new markets for DERs, DC power use, and microgrid deployment. In line with the above regulatory best practices, this includes leveraging international standards where applicable.
2. Economies should seek to streamline existing grid-related policies and permitting procedures, especially given the connectivity of DC and AC applications. This may include, for example, policies preventing the discrimination between AC and DC microgrids.
3. Economies are encouraged to explore “sandbox models” for pilot projects of DC power and microgrid applications. Under such models, organizations apply for their investment to qualify for a sandbox designation. If approved, the organization can deploy these technologies under a relaxed regulatory environment and help inform regulators on how policies can best be tailored to the use case.
4. Regulators should adopt practices to improve inter-agency coordination and stability in the regulatory environment. Such stability creates long-term investment horizons that attract a more diverse set of investors for projects with higher risk.
5. Governments should adopt formal programs to improve the expertise of their workforces on DC power and microgrids. This includes encouraging formal roles for women’s leadership and participation.

CONCLUSION & NEXT STEPS

There is wide recognition of the potential applications of DC power and microgrids towards addressing APEC economies goals and challenges. In a post-workshop survey (See Annex II), workshop participants said this APEC workshop was an effective platform for sharing learnings and best practices to accelerate the development and deployment of DC power and microgrids.

All respondents reported growth in their understanding on the topics, including broad insights into obstacles to trade and investment in microgrids and DC power systems. They also reported an improved understanding of the practical applications of DC power and microgrid usage and the critical importance of safety and regulatory frameworks to supporting investment.

With this improved understanding, respondents plan to identify local gaps in policies and draft regulations related to microgrids and DC power systems. Additionally, they intend to share information with colleagues and local stakeholders, design training programs, seek to incorporate more smart grid technologies, and develop regulatory policies that uphold safety, mitigate risks, and encourage private sector participation.

As APEC economies look to next steps, workshop participants were asked to identify what new workstreams or initiatives need to be done by APEC to support them. Some proposals include:

1. Consider case studies on facilitating trade of other related products, including batteries and electric vehicles.
2. Provide technical assistance to learn more about standards development and regulatory frameworks.
3. Develop a report on the status of DC microgrids in various aspects of the value chain and share best practices for small-scale non-commercial options.
4. Conduct regular training programs, including site visits to DC power generators and microgrid systems.

ANNEX I: Workshop Participation and Agenda

The Workshop on Driving Trade & Investment for DC Power Systems and Microgrid Frameworks Through Public Policy Alignment was hosted on 24-25 February 2025 at the First Senior Officials Meeting in Gyeongju, Republic of Korea. The workshop convened 66 public and private sector experts from 16 APEC economies and 1 non-APEC economy. A breakdown is provided below:

Category:	**Number:**
Total participants:	66
Gender Breakdown:	43 male, 23 female
Public/Private:	International Organizations: three • World Trade Organization • Asia Pacific Energy Research Centre (APERC) • APEC Sustainable Energy Cener (APSEC Public Sector: 45 Private Sector: 15 Academia: four
Economies:	17 economies: • Canada • Chile • People's Republic of China • Hong Kong, China • Indonesia • Japan • Republic of Korea • Malaysia • Mexico • Papua New Guinea • Peru • The Republic of the Philippines • Switzerland • Chinese Taipei • Thailand • United States • Viet Nam

AGENDA
First Senior Officials Meeting, 2025: Energy Working Group 69 (EWG69)

Driving Trade & Investment for DC Power Systems and Microgrid Frameworks Through Public Policy Alignment

24-25 February, 9:00 am – 5:00pm, Hwabaek Convention Center (HICO), Room 105-106
Gyeongju, Republic of Korea

This two-day workshop aims to facilitate trade and investment of technologies critical to the clean energy transition. More specifically, the workshop will:

- Convene experts to share experiences identifying and addressing barriers to trade/investment to advance the energy transition
- Build capacity of APEC members to promote energy security and low-carbon energy systems
- Foster alignment of regulatory and conformity assessment approaches for DC power and microgrid systems with international best practices
- Align on and document policy recommendations and share best practices for public and private sector participants from around the region

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Day 1, 24 February, 2025	
15 minutes 9:00 AM – 9:10 AM	**Opening remarks** The theme of Day 1 is to align on objectives and learn from governments and industry about successes and challenges in investments/initiatives in microgrid and DC power technologies from across the APEC region. • Christian Roatta, Senior Trade & Multilateral Affairs Specialist, UL Solutions, PO for APEC/ EWG 04 2023S
20 minutes 9:10 AM – 9:30 AM	**Session 1 – Microgrids for a Just Energy Transition** Presentation on the outcomes and recommendations from the October 2023 APEC Workshop on Microgrids for a Just Energy Transition (EWG 04 2023S).[9] This session will provide the audience with an introduction to the key concepts of this Workshop and review the results of the Phase 1 survey of project economies. This session aims to provide a baseline upon which subsequent discussions will build. **Speaker:** Christian Roatta, Senior Trade & Multilateral Affairs Specialist, UL Solutions, PO for APEC/ EWG 04 2023S
60 minutes 9:30 AM – 10:30 AM	**Session 2 – Panel: Microgrids and DC Power Innovation** Combination of cross-sectoral panelist presentations (6 - 8 minutes each) and facilitated Q&A, discussion and brainstorming, focused on recent technological developments and successful applications of DC power and microgrids. **Panelists:** • Dr. Worajit Setthapun, Lecturer, Asian Development College for Community Economy and Technology (adiCET), Chiang Mai Rajabhat University, Thailand • Dr. Hyosung Kim, Professor Emeritus, Kongju National University, Republic of Korea **Moderator:** Rick Ziegler, Director, Trade & Multilateral Affairs, UL Solutions, United States
30 minutes 10:30 AM – 11:00 AM	**Coffee Break**

60 minutes 11:00 AM – 12:00	**Session 3 – Panel: Successes and Challenges to Investment** This session will provide public and private sector stakeholders the opportunity to highlight their experiences and recommendations for investment in DC power and microgrid technologies (6-8 minutes each). Q&A will follow. This will not only enable APEC economy governments to learn from private sector experiences but also enable these organizations can learn from one another. **Panelists:**

[9] This workshop builds on the preliminary recommendations from the foundational October 2023 workshop: https://www.apec.org/publications/2023/12/apec-workshop-on-microgrids-for-a-just-energy-transition

	• Santiago Barcón, CEO, PQ Barcon, Mexico • Mr. Inki Choi, Senior Manager, Strategy & Marketing, Bloom Energy Korea, Republic of Korea **Moderator:** Rick Ziegler, Director, Trade & Multilateral Affairs, UL Solutions, United States
1 hour 30 minutes 12:00 PM – 1:30 PM	**Lunch**
45 minutes 1:30 PM – 2:15 PM	**Session 4 – Case Studies on Small Island Microgrids, Flexible DC Power Systems, and Renewable Energy Integration** This session will feature presentations by representative from the Philippines Department of Energy and from the People's Republic of China, Global Energy Interconnection Group Co., Ltd. This will be followed by Q&A. **Speakers:** • Luningning Baltazar, Director III, Department of Energy, The Philippines • Dr. Chen Chen, Research Fellow, Global Energy Interconnection Group Co., Ltd, People's Republic of China • Dr. Hathaithip Sintuya, Dean, Asian Development College for Community Economy and Technology (adiCET), Chiang Mai Rajabhat University, Thailand
45 minutes 2:15 PM – 3:00 PM	**Session 5 – Case Study: Successes and Challenges to Microgrid and DC Power Initiatives in the Republic of Korea** **Presenters:** • Dr. Jinhong Jeon, Director of the Distributed Power System Research Center at the Korea Electrotechnology Research Institute (KERI), Republic of Korea • Prof. Dongjun Won, Inha University, Chair of the Technical Committee of the Korean Institute of Electrical Engineers, Republic of Korea • Dr. Yonghak Kim, Director General, Energy New Tech Research Center, Korea Electric Power Corporation (KEPCO), Republic of Korea **Moderator:** Gwen Wang-Reeves, Engagement Director, GE Vernova
60 minutes 3:00 PM – 4:00 PM	**Session 6 – Panel: Opportunities and Challenges for Emerging and Developing Economies** This panel will focus on the specific considerations for emerging and developing economies as they look to leverage DC power and microgrids. This includes, but is not limited to, simultaneously enabling investment while protecting consumer safety. The session will feature perspectives from multilateral development and finance organizations. **Panelists:** • Danae Cancino, Regulatory Analyst, Ministry of Energy, Chile • Santiago Barcón, CEO, PQ Barcon, Mexico • Anastasiia Koltunova, Legal Officer, World Trade Organization

	Moderator: Gwen Wang-Reeves, Engagement Director, GE Vernova
5 minutes 4:00 PM – 4:05 PM	**Closing remarks**

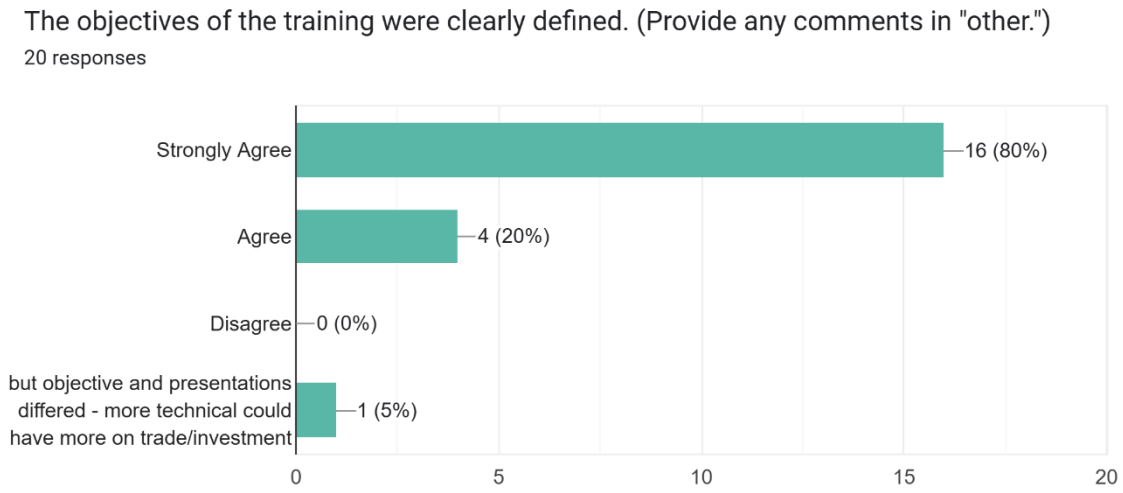
Day 2, 25 February, 2025	
5 minutes 9:00 AM – 9:05 AM	**Opening remarks** The theme of Day 2 is to identify specific regulatory challenges and policy recommendations to enabling DC Power and Microgrid investments, including through case studies and breakout sessions.
45 minutes 9:05 AM – 9:50 AM	**Session 1 – Eliminating Barriers to Trade Through Compatible Regulatory Frameworks for Microgrids and DC Power** Presentations followed by Q&A focused on understanding the critical role of regulatory frameworks as applicable to DC power and microgrid technology, including topics of conformity assessment (testing, inspection, certification, etc.) and key differences in regulatory frameworks among economies. It will also cover issues related to Technical Barriers to Trade (TBT) and facilitating trade of goods key to the energy transition. **Presenters:** • Christian Roatta, Senior Trade & Multilateral Affairs Specialist, UL Solutions • Anastasiia Koltunova, Legal Officer, World Trade Organization
45 minutes 9:50 AM – 10:35 AM	**Session 2 – Case Study: Enabling Business Models in Mexico** Presentation and Q&A by **PQ Barcon's CEO, Santiago Barcón**. The case study will overview PQ Barcon's support of low, medium, and high voltage systems, as well as experience overcoming investment and operations challenges in Mexico.
25 minutes 10:35 AM - 11:00 AM	**Coffee Break**
60 minutes 11:00 AM – 12:00 PM	**Session 3 – Panel: Conformity Assessment, Standards, and Facilitating Investment** This panel session would convene government and private sector experts to discuss the roles of conformity assessment and standards in enabling investments while preserving their safety, security, and sustainability. It will feature insights from delegates to the APEC Sub-committee on Standards and Conformance (SCSC). **Moderator:** Christian Roatta, Senior Trade & Multilateral Affairs Specialist, UL Solutions **Proposed speakers:** • Man Thuy Giang, Manager, Viet Nam National Standards and Quality Institute - Commission for the Standards, Metrology and Quality of Viet Nam (STAMEQ), Viet Nam

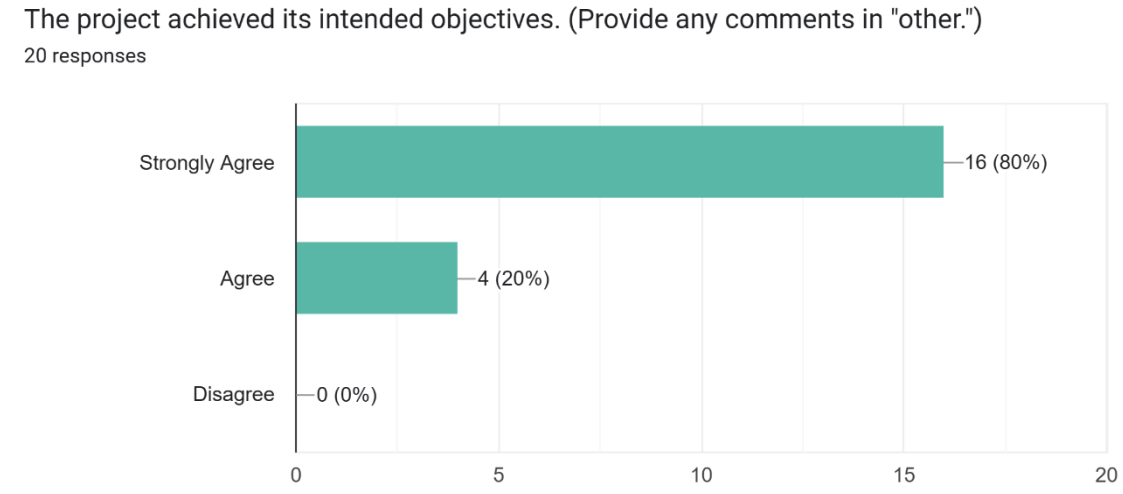
	• Joseph Conrad, Senior Program Administrator, International Development, American National Standards Institute (ANSI), United States
1 hour 30 minutes 12:00 PM – 1:30 PM	**Lunch**
3 hours 30 minutes 1:30 PM – 5:00 PM	**Breakout sessions** Participants and speakers will convene in small groups to discuss the following topics. At the end of each 35-minute session, one person will read out recommendations from that small group. At the end, group leads will be invited to consolidate and align recommendations as part of a short panel. **Moderators**: UL Solutions (PO for EWG 208 2023A) **2:05 – 2:50 PM, Topic 1:** What are the major considerations for governments when seeking to facilitate investment in DC power and microgrid technologies? What are the primary applications and interactions of these technologies? **2:50 – 3:35 PM, Topic 2:** How are private sector actors working in this space? What are examples of success and how did they overcome challenges? What lessons can be extracted from their experiences? **3:35 – 4 PM, Coffee Break** **4:00 – 4:45 PM, Topic 3**: Looking forward, what are innovative approaches to public policy alignment that APEC economies can undertake to overcome investment challenges? How can economies emphasize and promote female participation? **4:00 – 5:00 PM, Panel**: Leads from breakout groups come together to present and align on recommendations, facilitated by the moderators. This includes a discussion on how to leverage the findings of the workshop in future reports and publications.
5 minutes 5:00 PM – 5:05 PM	**Closing remarks** Distill common themes and recommendations. • UL Solutions

ANNEX II: Evaluation Survey Responses

The APEC project evaluation survey was distributed at the end of the workshop to participants. There were 20 responses.

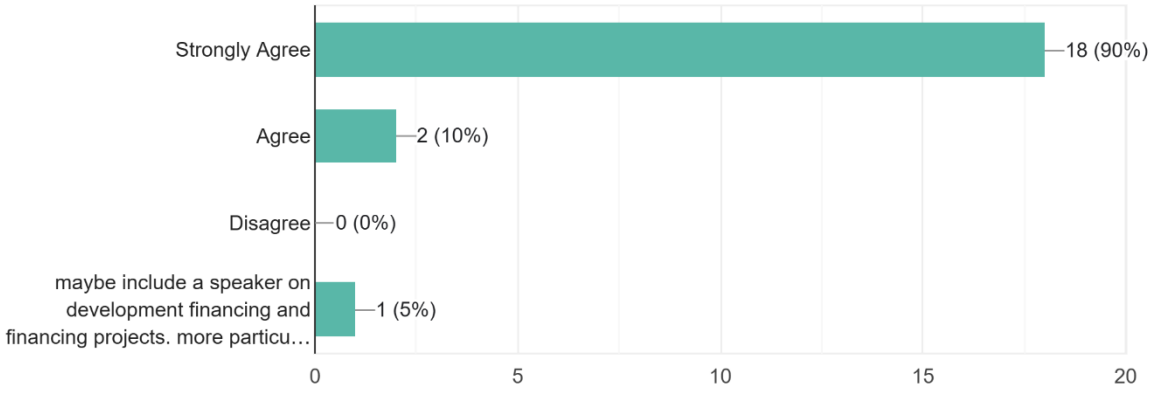
All respondents indicated an increase in knowledge resulting from the workshop.





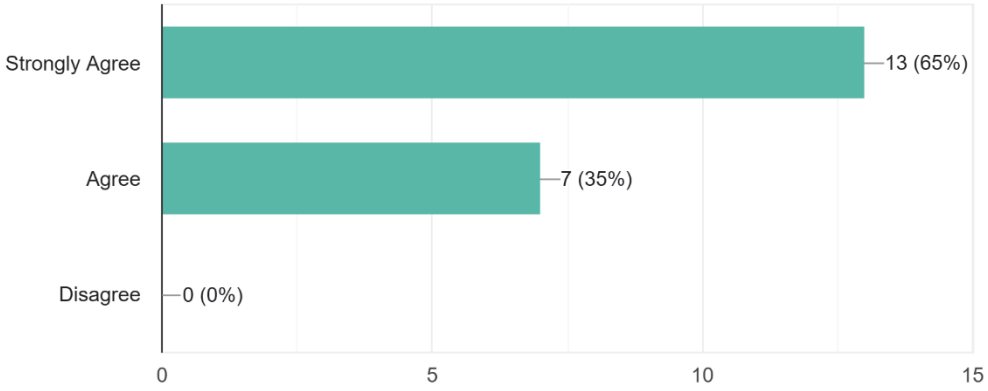
The agenda items and topics covered were relevant. (Provide any comments in "other.")

20 responses



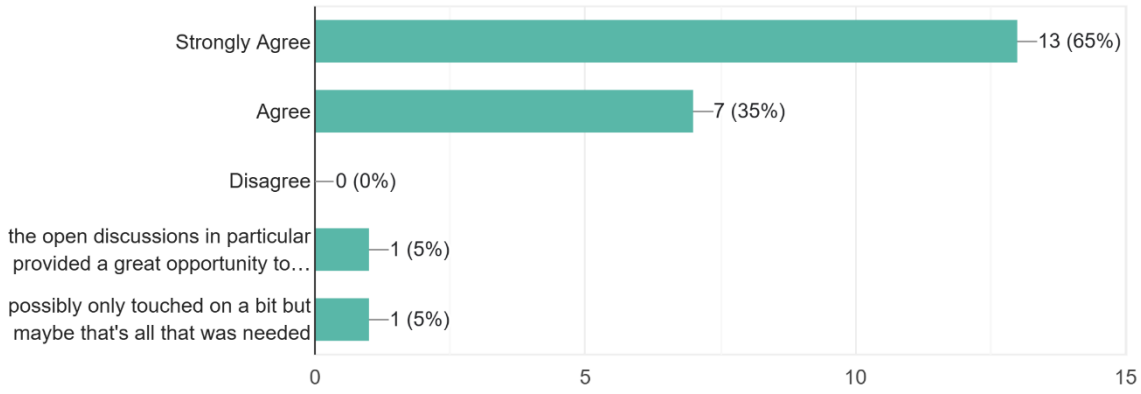
The content was well organized and easy to follow. (Provide any comments in "other.")

20 responses



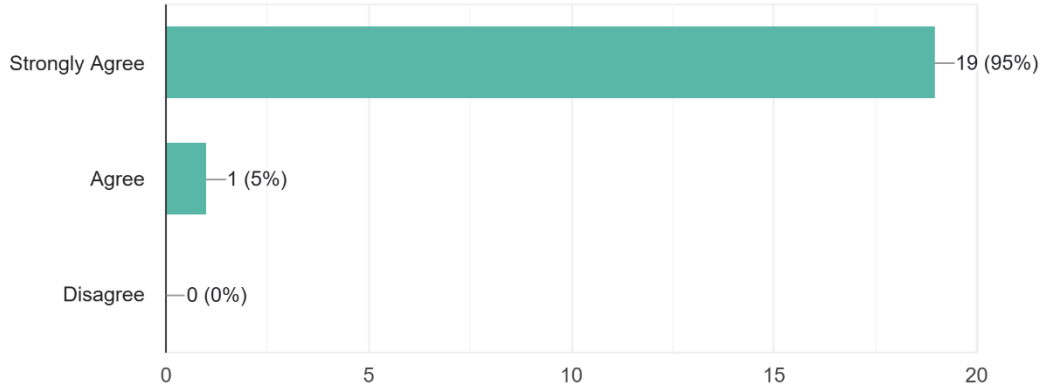
Gender issues were sufficiently addressed during implementation. (Provide any comments in "other.")

20 responses



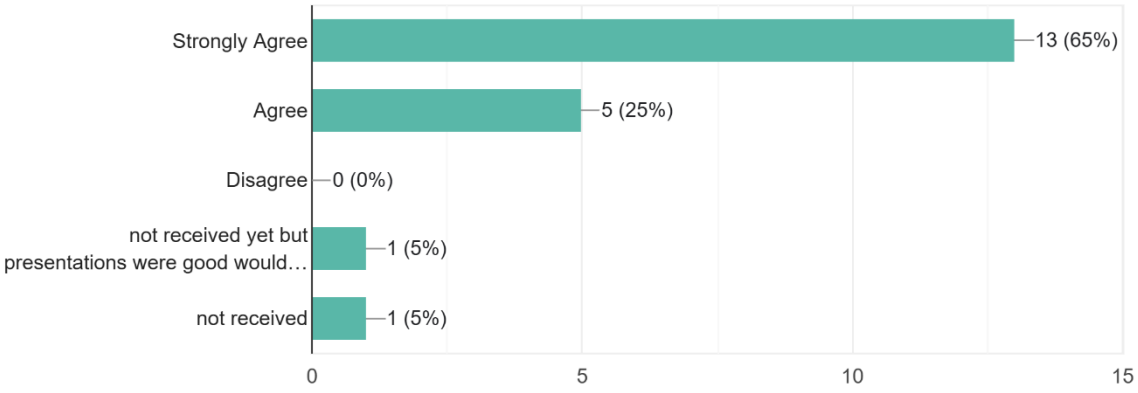
The trainers/experts or facilitators were well prepared and knowledgeable about the topic. (Provide any comments in "other.")

20 responses



The materials distributed were useful. (Provide any comments in "other.")

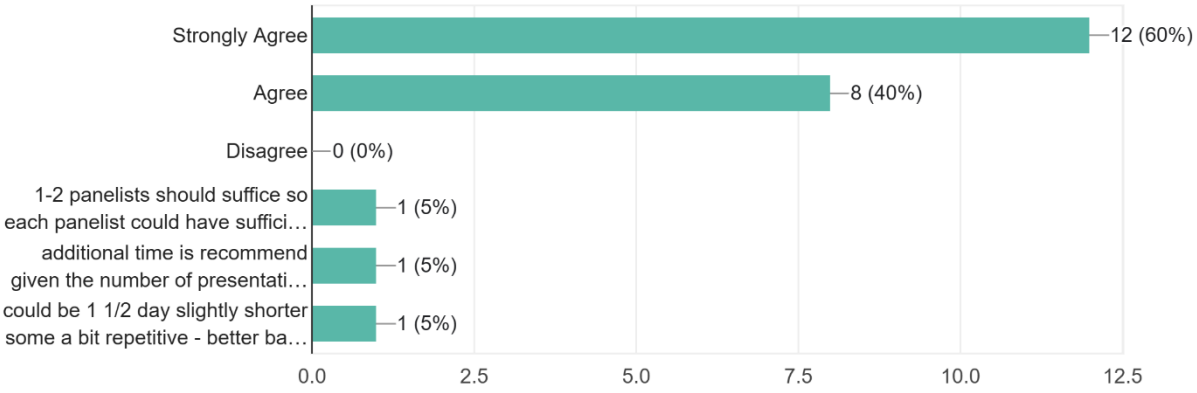
20 responses

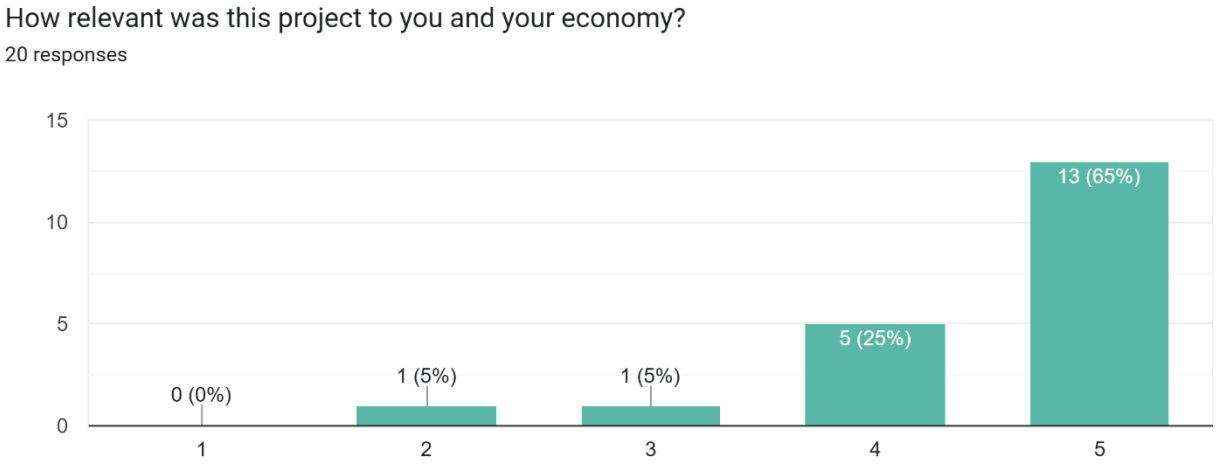


**At the time of the survey, final materials were still being distributed.*

The time allotted for the training was sufficient. (Provide any comments in "other.")

20 responses





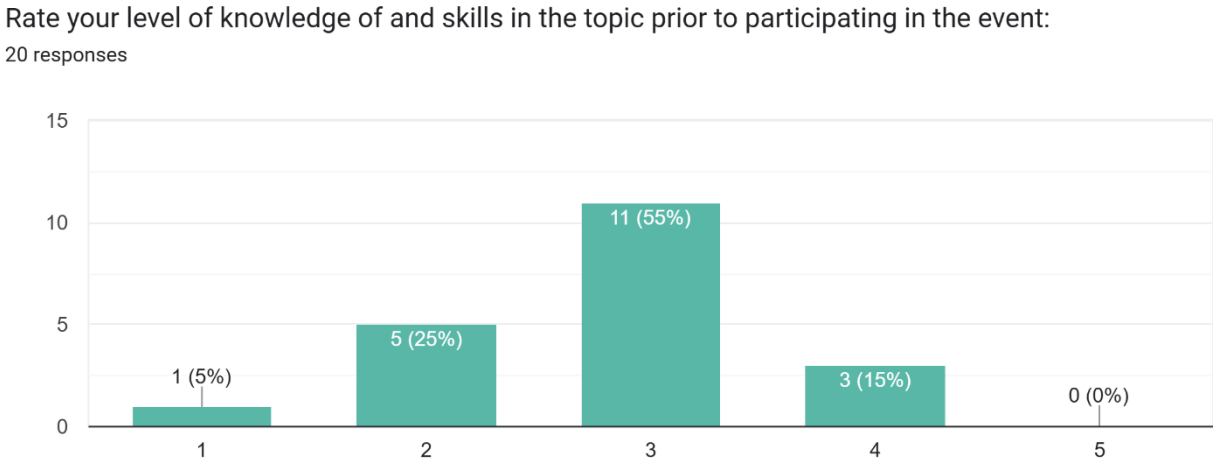
In your view what were the project's results/achievements? (18 responses)

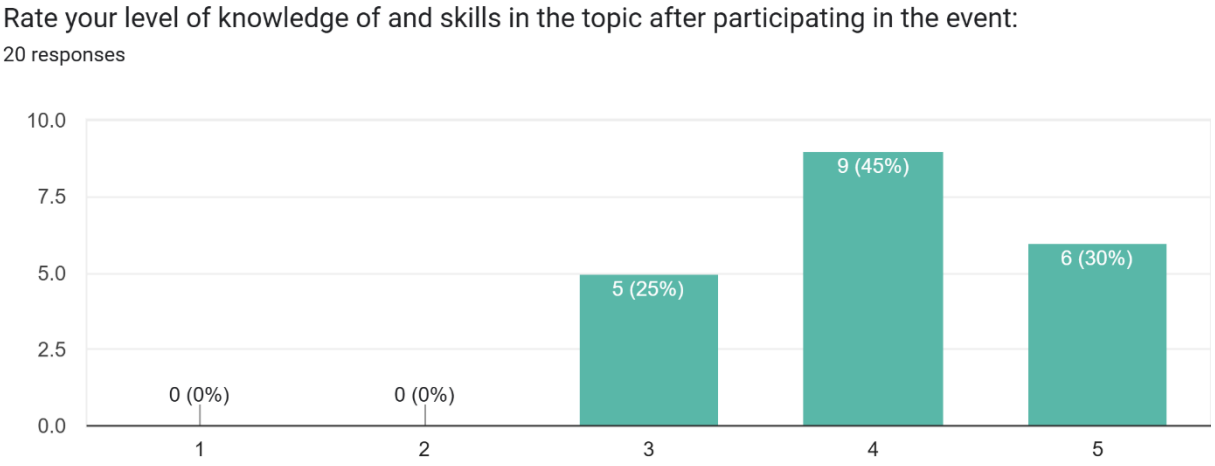
1. Driving knowledge of policies in the energy space with objective of supporting trade
2. Raising mutual understanding amongst APEC member economies with an aim of accelerating the development of DC and microgrid
3. The exchange was very productive. interesting topics and great diversity of opinions. good contacts made. developing new ideas and alternatives
4. Knowledge, technology and information sharing and achieving consensus on way forward to energy transition along with gender equality
5. Bridging all sector to see the opportunities and challenges for DC system and microgrid
6. All participants can exchange idea and experiences to move forward the DC power and microgrid to be in the most effective way in the future
7. Sharing info about microgrids
8. I believe this project could achieve its intended outcomes and have the participants knowledge improved
9. To communicate about cases and policy frame of DC power and microgrid
10. Clear the main factors and considerations for investment of DC and microgrid give some good cases and feasible solutions
11. The project extremely receive the attraction from all of member and so meaningful to each situation of economies
12. Education on DC microgrid best practices on policy standards and innovation
13. Sharing knowledge and experience between economies
14. A platform for not only APEC economies but also for organizations to share and provide feedbacks for improvement
15. Development for economies that have not yet achieved it
16. Alignment of policy direction
17. yes

18. Better alignment on investment needs and enabling factors

What new skills and knowledge did you gain from this event? (19 responses)

1. Multisectoral understanding related to obstacles to trade and investment in the areas of microgrids and DC power systems
2. Knowledge of stakeholder community and breadth of stakeholders involved
3. Technical knowledge and real-case experiences from various economies
4. Better knowledge of alternative in DC microgrids
5. AC and DC options, other microgrid solutions
6. Standard, CA frameworks
7. Microgrid standard
8. Greater understanding of standards/certifications
9. Microgrid technology
10. Technical framework of DC and microgrid technology, how economy implement the tech and do research to boost innovations
11. The frame of conformity assessment
12. The different situation of economies for microgrid and DC some good solutions and some successful case
13. Through attending this event, I gain much more experience, major knowledge, view about DC energy and microgrid system
14. Knowledge about DC power, microgrid standards, investment and case studies in relevant economies e.g., Viet Nam and Thailand
15. Experience from other economies on microgrid and DC power
16. Application for practical microgrid usage from Thailand and Korea
17. I have gained knowledge to bring back to my economy
18. Sandbox concept
19. Importance of standards and safety and how to enhance microgrid participation





How will you apply the project's content and knowledge gained at your workplace? Please provide examples (e.g., develop new policy initiatives, organize trainings, develop work plans/strategies, draft regulations, develop new procedures/tools etc.). (19 responses)

1. Case studies
2. Continue to help and guide international policy and regulatory frameworks
3. The learning obtained from this workshop allows me to refine GEV strategies for APAC region
4. Write about microgrids (DC) and train young engineers
5. Develop policy initiatives on ensuring sustainable operation of microgrids, improve terms of reference in subsequent
6. I would like to find out more about standardization process and implementing bodies for my economy
7. The content and knowledge gained can be used to design the program for training people to understand and get ready to apply new technology
8. Engage internal experts to discuss gaps between government funding and private investment as well as challenges related to funding timelines/phasedown
9. Will share with experts to ensure they are aware
10. I will disseminate information gained in this program not only to the colleagues within the org but also coordinate further with the related stakeholder. identify gaps in domestic level to formulate action
11. I was mainly focusing on technical research. now i have the fundamental understanding about the conformity assessment. perhaps communication talks to share what I've learned first
12. In some applications combines the useful considerations and share inside

13. With the accumulation of knowledge in this workshop and our organization's capacity, we will contribute technical procedure to improve the regulation of DC power and microgrid in our economy
14. Inform U.S. trade policy in promoting international standards in the energy space
15. Develop plan of domestic standards development, propose to organize workshop on DC power and microgrid
16. After this workshop, I definitely take the microgrid into consideration for our SMART grid project for Viet Nam
17. Develop work plans
18. Increase in the development of policies and regulations standards and safety that will enhance, re-risk, and encourage private sector participation on microgrids
19. Better implement TA activities for increased impact

What needs to be done next by APEC? Are there plans to link the project's outcomes to subsequent collective actions by fora or individual actions by economies? (16 responses)

1. We could consider specific case studies to facilitate trade of specific products (e.g., batteries)
2. 1 - share profiles of participants well in advance; 2 - look into different projects
3. Provide special technical assistance in terms of developing standards, encourage investments in technologies and in enabling microgrids
4. Report on the status of DC microgrid in various aspect of the value chain
5. The standardization between economy should be further discussed
6. Continued work under JETI on funding / international standards / and enduring best practices
7. Share best practices for small scale non-commercial options as the seem to help
8. Conduct regular training program that also includes technical visit to the DC power plant and microgrid system
9. Organize workshop related
10. More capacity training and some successful skills and cases to share with
11. I think the supporters of APEC need more information on attendance
12. To establish focus on DC power and microgrid
13. Maybe electrical vehicle and their potential in APEC economies
14. Maybe electrical vehicle and their potential in APEC
15. Yes especially on developing standards and possible development and investment to microgrid in the Philippines
16. Identify opportunities for collaborative TA, investment ,and capacity development to build regional and local capacity and drive multi-economy investment activities

How could this project have been improved? Please provide comments on how to improve the project, if relevant. (15 responses)

1. it was an excellent workshop which enabled constructive dialogue and exchange. the workshop was very well organized.
2. somewhat concerning that concurrent events may have impacted continuity of participation
3. look forward to furthering engagements following this soon!
4. more control on time taken by panelists
5. needs assessment for participating economies can be conducted to prepare for plan of action
6. create opportunity for government and private sector to start the collaboration
7. seeking less technical knowledge, more policy knowledge/advice. investment approaches were only lightly touched on
8. keep engaged with the participant and speakers, initiate a follow up training, involve more industry related and standardization body
9. no comments
10. well-prepared materials and send it participants before meeting
11. this is the first time I join APEC workshop but I feel this is a good occasion to get knowledge. everything is ok.
12. intersperse discussion in between panels instead of all at the end to retain audience engagement. have more dedicated group discussions and networking.
13. none
14. I love the paperless APEC but some key takeaway material would be great!!!
15. this is the first time I join with APEC

Organization/Economy (identifying information is optional): (13 responses)

1. Private sector
2. GE Vernova
3. PQ Barcon
4. Canada
5. BSN/ Indonesia
6. Global Energy Interconnection Economic and Technology Research Institute / China
7. China
8. Viet Nam, STAMEQ
9. Viet Nam
10. Ministry of Industry & trade
11. MINISTRY OF INDUSTRY AND TRADE
12. The Philippines
13. The Philippines, Department of Energy

Respondents Gender: (13 responses)

eight male, five female

ANNEX III: Presentation Materials