Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

Off Grid Electrification Option for Remote Regions in APEC Economies

APEC Energy Working Group

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Executive Summary:

Project Background:

There is large ratio of developing economies in APEC region, and many of them have remote regions or islands that have no access to the electricity grid at all. A lack of access to electricity hinders the economical growth of these developing economies**.** Bring electricity to these regions is one crucial factor to improve the living conditions of local residence, promote economical growth and strengthen the community resilience in these regions. This project will focus more on building capacity needs in developing economies rather than developed economies; the goal is to bring clean, renewable and more efficient electrification option to these regions. During the project implementation process, it will work closely with local people and provide awareness to all levels from the local government officials, corporations, financial agency, technology experts and citizens, to provide awareness and also promote the implementation of clean energy such as solar, wind, battery, microgrid (including DC microgrid) technology as means for economic development.

Project Objectives

The project objective is to study the off grid electrification option in remote regions in APEC economies. The project team will on- site investigate at least three representative regions for the feasibility study, two regions from developing economies and one region from developed economies, and to investigate the current off grid electricity option, the cost, problem and obstacles of providing electricity, and to assess the technology and economical advantages of adopting solar, battery, microgrid and DC microgrid to these regions. At the end of project, a one day workshop is to be conducted to facilitate in-depth discussions, sharing ideas and developing strategies to implement clean and efficient energy solution in these regions.

Project Outcomes:

We have successfully completed on- site investigation at China, Chile and Australia, investigated the local current off grid electricity status, the cost, problem and obstacles of providing electricity. Interviewed multiple levels of related parties, such as local residence, energy experts, university scholars and local government representatives. Promoted the awareness of the technology and economical advantages of adopting solar, battery, microgrid and DC microgrid to these regions by discussion and giving out several seminars. We also have successfully organized the one day workshop on Sep 10, 2018. There are total of 12 speakers at the workshop and more than 30 attendees attended the workshop. At the end of the workshop, a round table discussion produced valuable summary on common problems encountered to provide electricity to remote off grid regions, such as how to sustaining the efficient electrification supply after the projects are completed, and suggestions on how to solve these problems. Following are the detailed report.

On Site Visit of Three APEC Economies:

We have completed the on-site study at three economies, China, Chile, and Australia, the summary are as follows:

On Site Visit to China:

The team for on site visit to China including: Professor Fengyan Zhang, Associate professor Peng Zhang, students of Jiabin You, Xin Lin, Dehong Wu, Xingyu Xiong, Hangjie Lin, Lily,Candy, Shiwei Wang, Zeyu Jiang.

Figure 1. Team member of on site visit to China

The team on-site investigated the current electricity supply status and the microgrid project at Dong Fu Shan Island in China. Interviewed the local residence, discussed with the energy experts and local government officials about this microgrid's original design and implementation, the problems encountered later on and the importance of continuous support from the government.

Dongfushan island is the farthest east island in China east coast. The village is mainly a tourist spot during the summer. While there is no grid connected to the island, the local residence was relying on the diesel generators to power their homes during the busy summer season. The situation using diesel power is expensive, unreliable and often interrupted service. On 2011, the government granted pilot funding and installed a wind, solar, battery, and diesel power microgrid to provide electricity to the island.

At the initial stage, the system was running well, although the capacity was still very limited, the microgrid was not be able to power air conditioners to the local residence due to the large peak demand. The residence were complaining about they normally can only run less than 30 min AC each day before their circuits get tripped. Although the cost of electricity from microgrid was lower and it is about 1/3 comparing with using the diesel generators only, due to the unreliable electricity supply situation, the residence were still very reluctant to pay the electricity, which should be an important factor for sustainable business model.

Figure 2 Dong Fu Shan island

Figure 3. Dong Fu Shan island village

Figure 4-7. Interviewing local residence

Further more after several years of the installation of the microgrid, more problems started to occur. One major problem was the maintenance issue. Due to no continuous funding was secured for on going maintenance expenses, which could run around $80K per year, and the local residence, are not trained well to maintain the system by themself, the microgrid started to deteriorate. The deterioration of the wind turbines were the first to happen due to: 1) the microgrid used small wind turbines which normally have higher cost and lower quality. And the warranty was only two years. After two years, they started to break down. One example is the harsh and corrosive environment has caused small wind turbines to rust easily and stopped working. 2) The original running design of the microgrid also has defect, which was designed to prioritize the continuous running of the diesel engine and obtaining longer running life of the battery array, so it has caused the wind turbine to be turned on and off too frequently, which has also caused damage to the wind turbines. 3) The capacity design of the wind turbine did not consider the seasonal energy usage of the island. Since it is a tourist island, it needs more energy during the summer than the winter. But the wind turbines produce more electricity in the winter than summer, therefore they have to either be shut down, or the extra energy generated to be wasted during the winter season, which has also caused harm to the wind turbines. 4) Poor wind quality on the island also caused wind turbine to not function at their best capacity and could got damaged. 5) The installation location of the wind turbines did not consider maintenance issue well, in order to be installed far away from residence, scenery, plantation, the wind turbines were installed in the place that has difficult road condition and the geography, which are major obstacles for timely maintenance of the wind turbines.

The second example was the deterioration of the battery system. There are two kind of battery system available at that time of the designing of the microgrid: 1) lead acid battery, which has short life span but is cheaper. 2) The lithium ion battery, which has a longer life span, but they are more expensive, and sometime has safety concerns. DonFushan island microgrid used lead acid battery, which has short life span. So when these batteries reached their lifetime only after few years running, since there are no new funding secured to replace the old battery, the energy storage unit were basically lost its function.

The third example is the solar system, which were also cut off from the microgrid later due to a new water dam has to go through the same location. The solar farm were abandoned and the local residence actually used the solar penal to dry their fish.

Because of all these factors, the microgrid system was abandoned eventually. The local residence has to go back to the old diesel power. The supply of electricity became very limited and often interrupted again, During interviewing with the local residence, they still expressed strong interest for using solar panels to power their home. Since most of their house roofs are flat, which would be beneficial for installing solar panel on their roof directly. But they also express lots of concerns about the cost, durability of the system, maintenance issues, and warranty of the system. Since the harsh environment of the island, solar panels maybe deteriorate much faster, which can also potentially increase the cost of the system significantly.

Figure 8. Comparison of the wind and solar system after several year of usage.

Figure 9 Flat roof of the residence house

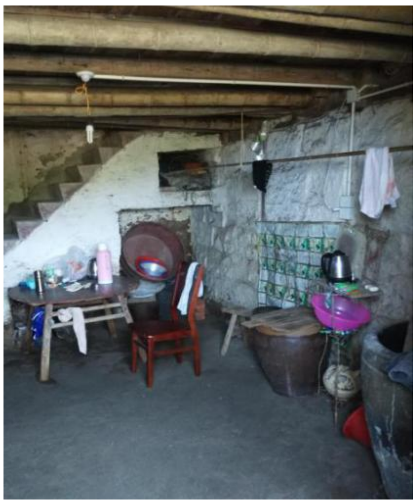

Figure 10 inside of the residence home

The team has discussed with different energy experts group and several levels of local government officials about the possibility of using an interconnected small DC microgrids for the village, since it will be able to supply DC power from the solar panel to DC lighting and DC air conditioning, which should deliver higher efficiency and more reliability electricity supply to the village. Also, the proposed DC microgrid will not use wind turbine, instead, it will mainly use solar and battery system, and with the diesel engine as the back up supply. But the major problem to adopt DC microgrid will be the availability of the consumable DC loads products, such as DC LED lights, DC fans, DC TV, DC cooking appliance, DC refrigerator and DC air conditioner. Although the research team at Xiamen University has demonstrated the feasibility of the technology and a pilot system with test models of DC LED lights, DC fans, and DC air conditioner etc, but in reality the residence may have difficulty to purchase them conveniently at their local store. On the other hand they can easily purchase AC lights and varies AC appliances if using an AC microgrid. Therefore the team concluded it would not be feasible to use DC microgrid for the village in the near future. But the team are collaborating with several institutes to consider setting up a DC microgrid demo on the island to further study the feasibility.

Conclusion from On Site Visit to China:

The clean and renewable energy including solar, wind, battery and microgrid technology have reached the stage that are more technology mature and economical affordable than traditional diesel generators for suppling electricity to off grid and remote regions. The problem and difficulties to adopt solar, battery, and microgrid to remote off grid regions are actually more due to the off grid regions' hard to reach geographic location, lack of telecommunication availability, ongoing maintenance issue, lack of local residence education and involvement, and lack of continuous maintenance budget supply. Feasible business model for more sustainable way to maintain long term reliable energy supply are critically needed. How to integrate the investment, design, installation and maintenance team together, to secure long term funding for the on going maintenance, and to gain continuous support from the business partner and government support, are all important factors for sustained electricity supply for the remote off grid regions.

In terms of using DC microgrid for the off grid island, besides facing the same issues mentioned above, it has extra limitation on the availability of the DC loads products, even though DC microgrid provide higher efficiency and better reliability, the technology is not suitable for remote off grid region at the present time.

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On Site Visit to Chile:

The team member of on site visit to Chile including Professor Fengyan Zhang, Professor Dennis Gusman, Professor Guillermo Jiménez Estévez, who is Director CE-FCFM at Universidad de Chile, and two of his associates.

Figure 11 & 12. Team member of on site visit to Chile

The team on-site studied the existing electrification status in remote off-grid region at Ollague, Chile, between 14-20 March 2017, studied this remote village's electricity status, visited the microgrid installed in the village, interviewed local maintenance person and residence, discussed the communities electricity demand, the electricity cost of today and old days, evaluated some problems associate with microgrid.

This village is currently powered by a solar- battery-diesel generator micro gird. It is a hybrid off-grid project with solar PV: 205 kWp (Thin film modules); storage: 752kWh (Sodium Nickel Chloride tech.); mini wind turbine: 30 kW; backup diesel generator: 410 kVA; and separate dish stirling engines (2) for providing warm water to school. PV and wind generation directly feeds Ollague grid. Excess energy is stored in the BESS that supply energy overnight. GenSet operates to sustain the load as backup generator; provide safety charge when BESS SOC falls below threshold values, and perform BESS equalization and to reach top of charge.

After installation, this project has successfully reduced the consumption of fossil fuel, and changed the habits of the inhabitants. The economic benefits includes: promoted existing and also created new small businesses (1 new hostel, 2 new laundromats, better situation for restaurants due to possibility of a refrigerator, 1-person business offering street food at the border with Bolivia). It also provided hot shower for 30 students of the school, and provides the possibility to maintain refrigerated medicines.

(Although it is need to be specified the windmill is not currently (as of March 2019) operating, because one of the pales is broken. Further, some batteries are failing and the software controller will be adjusted in order to maximized the solar production.)

Figure 13&14. Village of Ollague, Chile

Figure 15 &16. Team member were Interviewing the grocery store owner

Figure 17&18. Interviewing with local maintenance manager

The team also visited the local school for the children who live at the villager. Since there are limited children with large age difference are attending the school, they have to put the children from different grade in the same classroom, so the teacher can teach multiple grade of the students in the same room. The availability of electricity has improved the school conditions dramatically; the microgrid is able to provide electricity to regular classes, music classes, and sport utilities, a cafeteria, and also an indoor green house. It also provides the electricity for the one room library, with necessary office equipment, such as reading light, computers and printers, etc, which has proven to be very beneficial for the students.

Figure19. Local school

Figure 20. Students in the same classroom from different grades

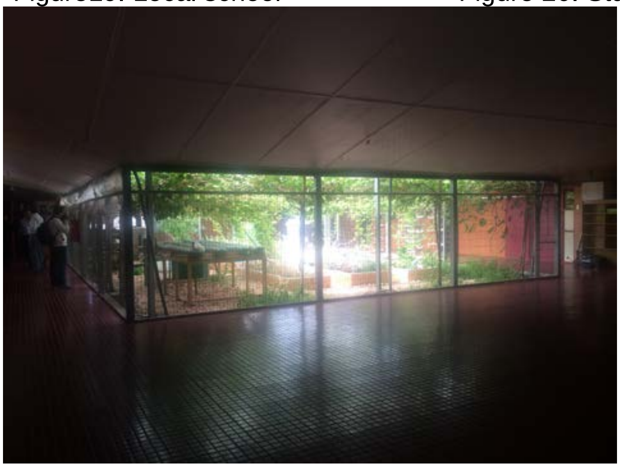

Figure 21. Green house inside the school

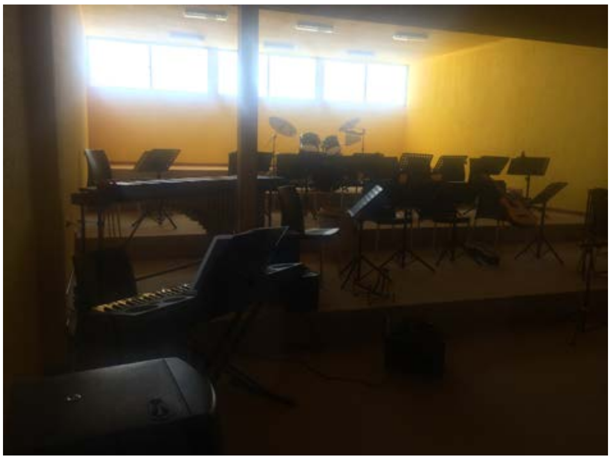

Figure 22. Music classroom

Figure 23 School library

Figure 24. Inside of school library

The team also discussed some problems associate with the microgrid, such as the quick degradation of solar panels used in the microgrid due to the harsh environment, large temperature swing between day and night (22C) and extreme solar radiation in rarefied atmosphere in the high desert. In collaboration with researchers at Xiamen University and CESM in Switzerland, the team has found out the possible causes of the problem and feedback to the local energy experts.

During the discussion, Professor Guillermo Jiménez Estévez summarized several important factors for the successful running of the microgrid: Microgrid has to be highly modular in order to manage any increase in consumption that cannot be easily forecasted; Sizing procedures should carefully balance overall system efficiency and reliability; Proper criteria for utility rate tariffs should be defined during the design phase to create awareness and appropriate incentives; Dynamic/advanced EMS (Energy Management System) under analysis could optimize the microgrid energy flows using external variables such as demand forecast and weather observation/forecast as demand forecast, etc. His research team plans to further optimize the Energy management system by: Advanced weather forecast and nowcast technologies; Real time monitoring of the loads (for Load forecast); Looking to possible improvements of the genset management strategy; Evaluate further equipment making for optimal usage of the available resource; Integrate meters and provide innovative billing system: Enhance the system performance and services by installing a metering system in order to monitor the customer electricity usage and provide a prepaid service based on consumption.

Also the team discussed the potential technology and economical advantages of using DC solar technology with Dr Guillermo Jiménez Estévez and his team at CE-FCFM of University of Chile. They have concluded that even though DC microgrid provide higher efficiency and better reliability than AC microgrid, due to the current solar array is about several miles off the village, and also the local residence are more spreading and scattering, the DC microgrid is not suitable because the DC microgrid needs to be installed close to the loads, normally within 100metres, otherwise the power loss will be significant. But they did discussed the possibility on demonstrating a DC microgrid in the Easter Island at Chile to further evaluated the technology and economical advantages of using DC solar technology in off grid regions.


Figure 25 The battery system of the microgrid

Figure 26. Small wind turbine


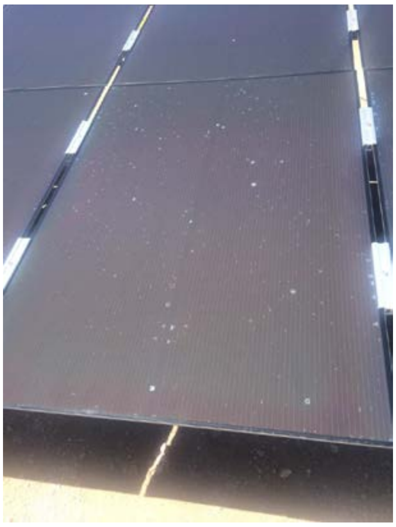

Figure 27. The solar system of the microgrid

Figure 28. Degradation of the solar panel

Conclusion from On –Site Visit to Chile:

The introduction of new energy technologies in rural regions is a challenge, since it generates changes in patterns of energy use; it is important to develop monitoring tools for Microgrids from the perspective of resilience, focused on the sustainability of the system, based on complex systems theory.

In a micro grid framework the resilience is very important. It is the capacity to absorb social, environmental, technical, and economical changes originated by low probability disruptive events with high impact, while quality of service is maintained. The key issues have to be considered are: 1) At design stage: robustness, flexibility; technical standards; training program; preventive maintenance; condition monitoring; and community feedback; 2) Provide the system to respond to disturbance without making changes to it: protective, SPSs; reserve margins; EMS emergency procedures; community contingency; 3) Elimination of disturbance sources: corrective maintenance; community recovery contingency plans; repairing; spare parts management coordination with stakeholders; 4) Integrating V2G solutions for rural microgrids; 5) Development of appropriate load‐frequency strategies , diesel engines adaptation, energy storage systems; etc. 6)The active participation of the local community is the key factor for sustainable operation of the microgrid; Its necessary to take into account the interactions between technology and people, as well as the consequences.

The DC microgrid is not suitable for remote regions with more spreading and scattered DC loads, since the energy supply needs to be close to loads (within 100meters). otherwise the energy loss will be significant.

On Site Visit to Australia:

The team member for Australia on-site visit including: Prof Fengyan Zhang, Dr Saad Sayeef, Professor Paul Mulvaney, Ph.D Students Jianghui Zheng and Xin Cui, Professor Pierluigi Mancarella and Prof Luis (Nando).

The team on-site investigated the current off grid electrification and available technologies status in Australia, interviewed with different energy expert groups in Australia, which including Dr Saad Sayeef, who is research engineer at The Commonwealth Scientific and Industrial Research Organization (CSIRO). Newcastle, Australia. He provided Australia off grid region's current electrification status and problems the economy is facing and the state effort and demonstration on electrifying the off grid regions in Australia. He introduced three microgrids they are working on: **Kalbarri Microgrid Project – by Horizon Power:** Kalbarri is a coastal town (>500km north of Perth) currently supplied by a 140km long rural feeder from Geraldton, and feeder's length and remoteness has lead to extended outages; They have installed solar, wind, combining with existing 33kV rural feeder line, and minimum of 2MWh battery storage to supply electricity to this region. **Alkimos Beach Project –by Synergy:** This is a large-scale battery storage trial for households with solar panels at Alkimos Beach in Perth's northern suburbs; 1.1MW battery in a shipping container connected to a line that feeds the subdivision; Allows households to store excess solar generation during the day and withdraw at night; Synergy's business model affected by rapid uptake of solar panels**; Standalone Power System (SPS) –Horizon Power and Western Power:** This is a Hybrid diesel/solar/battery power source; No connection to utility-owned distribution system; Usually a single customer, but not always; It avoids expensive reinvestment at the fringes of the network; it contains Solar: 8–12kW; Batteries: 16-33 units of 1.2kWh lithium ion batteries; Diesel:15-20kVA.

Dr Saad Sayeef also introduced their microgrid laboratory which is located at the CSIRO Energy Centre, This microgrid consists of distributed generation sources, on-site storage, a single point of common coupling to the utility grid and real world loads in the form of offices, labs and workshops. The computer controlled load bank provides up to 63kVA resistive, inductive and capacitive loads. These loads were implemented by discrete components sized in binary increments of 1, 2, 4, 8, 16, and 32kVA, so that a combination may be selected to produce any load in steps of 1kVA up to its maximum rating. The instrumentation system was installed to collect data at up to 8,000 samples per second. This is fast enough to enable study of transients and harmonics. The system consists of a National Instruments-based SCADA (Supervisory Control and Data Acquisition) system that relies on two PLCs (Programmable Logic Controllers) for control of the laboratory and 3 further PLCs for high speed data capture. The microgrid laboratory was designed to allow experimentation at two distinct levels. Grid connected and off grid island mode.

His team also discussed several difficulties for powering the off grid remote regions: **Cost** – the financial commitment to design and construct a microgrid can be significant; **Energy storage** – the market for which is continuously evolving and proprietary in nature, such that there is a wide variety of solutions accompanied by potentially significant expense and risk; **Complexity** - inherent to both the design and operation of microgrids generally, and in microgrid design for the specific application/location; **Information** – there is an absence of information about microgrid design and operation within the public domain; **Regulatory issues** – due to the lack of standard operating procedures, quality standards and OH&S standards specific to microgrids, and to facilitate interconnection with the surrounding grid where desired; **Technical expertise** – the relevant technical expertise may be difficult to obtain and retain at the local level; **Investor risk** – uncertainty over microgrid performance, user behaviour etc deters investment in Microgrids.

Other potential issues relevance for standalone (off-grid) microgrids in particular are that social and cultural issues were more difficult to solve than technical issues, Specific issues include: Partner selection; Theft;

Jealousy; Greed; Capacity building and a sense of ownership; Violent social conflict; and Rich versus poor. For example of one case study, the local village chief insisted that he be exempt from the demand limiters applied to the rest of the village before allowing the contractor to finish installation and commissioning of the village microgrid. As a result, the system ran out of power every day as a result of the chief's excessive use of electricity relative to the demand forecast that underpinned the system design.

Figure 29 Australia team members at CSIRO Energy

Figure 30 Microgrid system at CSIRO Energy

Figure 31 Energy storage unit at CSIRO Energy

Figure 32 Demonstration of the microgrid

Prof Zhang also met with Professor Paul Mulvaney who is FAA FRSC FRACI, and discussed the solar energy application status in Australia. Professor Paul Mulvaney showed Prof Zhang the ARC Centre of Excellence in Exciton Science (ACEx) at University of Melbourne which aims to develop flexible thin film solar cells to deliver low cost green power for Australia. Prof Zhang also met with Ph.D Students Jianghui Zheng and Xin Cui at Australia Center for Advanced Photovoltaic at UNSW, they have introduced solar energy research and development status in Australia, and showed Prof Fengyan Zhang the R&D activities and progress at Australia-US Institute for Advanced Photovoltaic.

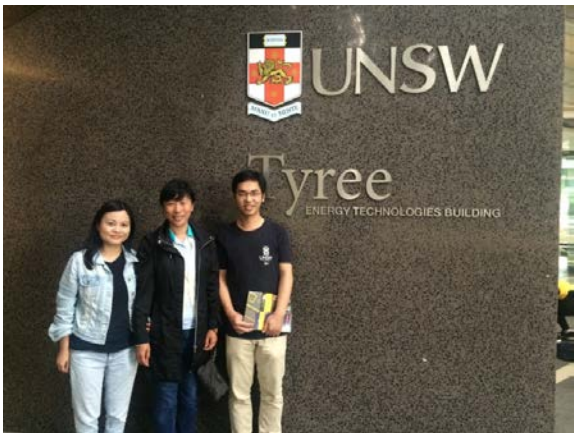

Figure 33 Australia team members at UNSW

Figure 34 Solar system at UNSW

A significant collaboration has been established with Dr Pierluigi Mancarella and Dr Prof Luis (Nando) Ochoa at Smart Grids and Power Systems at Department of Electrical and Electronic Engineering at University of Melbourne. They showed Prof Zhang the Smart grid lab where they are developing the microgrid technology and gave an introduction about the Kings Island microgrid project. They further exchanged outcomes from the projects they are conducting which involve provide electricity to remote regions in the developing regions in the world, such as India and Africa. They are teaming up right now to form a joint effort with Prof Pierluigi Mancarella in University of Melbourne, AU; Professor Richard Dawson, from Newcastle University, UK; and Professor MADYA DR GAN CHIN KIM from University Teknikal Malaysia Melaka and Sarawak Energy in Malaysia. The collaboration will further study the feasibility of using microgrid technology to provide resilience, reliability, efficient and clean electricity to the remote off grid regions around the world.

Prof Zhang also introduced the DC microgrid technology which exhibit better efficiency and reliability and could benefit not only the APEC economies but also to the more broad regions in the world.

1) higher efficiency because of fewer AC-to-DC, DC-to-AC, or AC-to-AC power conversions
2) higher reliability because fewer power conversions
3) lower capital cost because of fewer power electronic components and potential reductions in conductor cost because DC allows higher current carrying capability
4) A potential for lower control system complexity and higher survivability when subject to external and internal disturbances because of the elimination of synchronization requirements of AC systems.
5) Higher power quality and disturbance survivability because of the power electronics and (potentially) storage buffer between the DC microgrid and the AC grid.

While it has limitations for using DC microgrid for remote villages and islands, DC microgrid might be a good option for future net zero commercial buildings in the developed economies. The concept is to install the solar panel on the commercial building roof top together with centralized or distributed energy storage, and to power the DC loads inside the building such as DC LED lighting, air conditioning, office and residential appliance such as DC TV, DC refrigerator, DC cooking, which can increase the efficiency of the solar energy conversion, improve the reliability and lower the cost of the microgrid. Professor Fengyan Zhang has provides the detail design and technical aspects of the DC microgrid installed in Xiamen University, and proposed a design for the potential demonstration of a DC microgrid on commercial building in Australia.

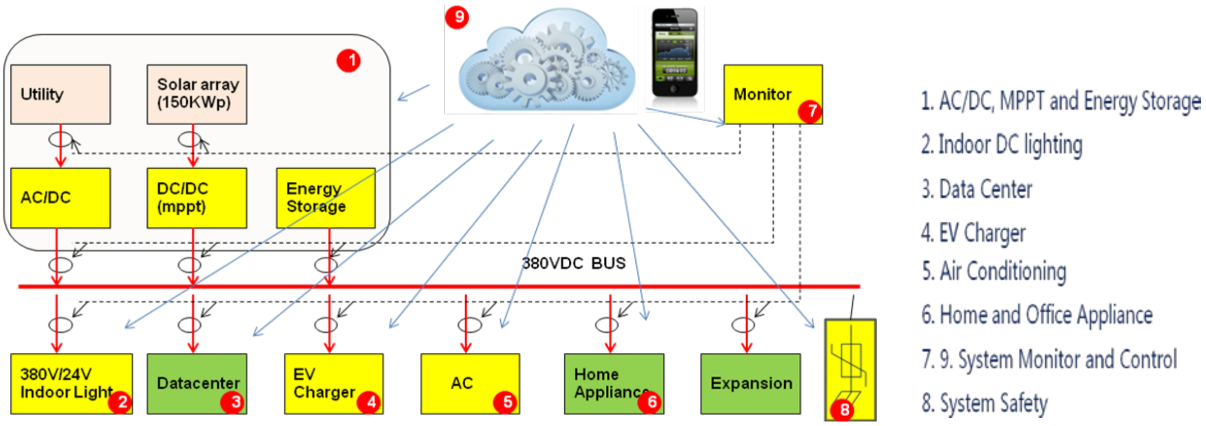

Figure 35 Proposed Design of DC microgrid for commercial building for net zero applications

Figure 36 & 37: New collaboration with Australia and Malaysia microgrid energy experts.

Conclusion from On Site Visit to Australia:

Even though still facing many challenges, there are more opportunities for powering the off grid remote regions in both developing and developed economies: **Technology cost reduction** – renewable energy and energy storage technologies are and will continue to rapidly decrease in cost; **Improved understanding** – on all aspects of microgrid design and operation emerging from a wide range of pilot projects; **Automation** – design and operation of microgrids is increasingly automated through the use of advanced/custom software; **Policy** – governments are increasingly identifying microgrids as a potential solution for various issues, leading to policy support in the form of regulatory reform and grant assistance; Australian Government policy is shifting away from renewable energy, promoting interest in standalone solutions for individuals/companies/communities; **Macrogrid support** – microgrids can provide back-up to the rest of the grid or cost-effective ancillary services, including in response to increasing environmental risks (climate-related or from foul-play); **Electricity price increases** – heightening the interest and appeal of distributed energy generation; **Diesel fuel price increases** – as the cost of diesel increases, the business case for renewable energy to replace diesel generation as back-up power or for rural/remote/isolated locations improves; **Grid modernisation** – is providing a more accommodating environment for microgrids, and is also facilitated incrementally by microgrid roll-out.

An important factors for successful electrifying the remote off grid regions is to include community involvement (via local contractors or volunteers) – this approach will help create a sense of community ownership that will reduce the likelihood of push-back, sabotage or theft; picking the right partner is very important – someone who knows the local culture, understands local issues and is knowledgeable of the technical challenges specific to the area.

DC microgrid might be a good option for future net zero buildings in the developed economies. The concept is to install the solar panel on the commercial building roof top, together with centralized or distributed energy storage unit as backup energy source and also for stabilizing the microgrid power supply, which can power the DC loads inside the building such as DC LED lighting, air conditioning, DC office and residential appliance such as DC TV, DC refrigerator, DC cooking. This way it can increase the efficiency of the solar energy conversion, improve the reliability and lower the cost of the microgrid.

One Day Workshop

We have successfully completed the one day workshop on 10 September 2018. There are total 12 speakers and more than 30 attendees come to the workshop. At the end of the workshop, a round table discussion produced valuable summary on common problems encountered to provide electricity to remote off grid regions, such as how to sustaining the efficient electrification supply after the projects are completed, and suggestions on how to solve these problems.

Workshop attendee selection:

The participant are recommended, nominated and selected by EWG and EGNRET representatives. We have also invited student representatives from Xiamen University who have participated the on-sites investigation in Dong fu Shan island in China to the workshop and gave presentation; these students are very interested in continuing working on related research and activities later on. We also invited experts from University Teknikal Malaysia Melaka and Sarawak Energy in Malaysia, with these experts we are going to continue collaborating on the new project to study Techno-Economic Framework for Resilient and Sustainable Electrification for developing economies. We have also developed new connection with experts from Australia and US, to further facilitate the ongoing effort to provide energy solution to remote off grid regions in APEC economies. All these effort will benefit and expend the APEC energy expert group's connection and promote continuously research and pilot projects in these fields.

<u>Participants/ Speakers Summary Table</u> (compulsory for events): Must be gender-disaggregated.

Economy *(Insert rows as needed)*	**# male**	**# female**	**Total**
Participants	22	8	30
Speakers	9	3	12



Figure 38 workshop photos

Table 1 Participants Table

Dr	Male	Titti	Saksornch	tumcus@gmail.com	Head of Renewable Energy and Energy Efficiency Promotion	Engineering and Planning Division for PEA District 1, Chiang Mai	Thailand
Dr	Female	Worajit	Setthapun	worajit@gmail.com	Dean	University	Thailand
Dr	Male	Cary	Bloyd	cary.bloyd@pnnl.gov	Senior Staff Scientist	Pacific Northwest National Laboratory	The United States
Mr	Male	Leon R.	Roose	lroose@hawaii.edu	Chief Technologist	Hawaii Natural Energy Institute	The United States
Dr	Male	Gan Chin	Kim	ckgan@utem.edu.my	Associate Professor	Universiti Teknikal Malaysia Melaka (UTeM)	Malaysia
Mr	Male	Christopher Wesley	Ajan	christopherwesley@sarawakenergy.com.my	Manager, Renewable Energy Division	Christopher Wesley Ajan	Malaysia
Dr	Male	Paul	Rodden	Paul.Rodden@ekistica.com.au	Senior Project Manager	Ekistica	Australia
Mr	Male	Jiabin	You	32420152202532@stu.xmu.edu.cn	student	Xiamen University	People's Republic of China
Ms	Female	Fengyan	Zhang	fengyanzhang1@gmail.com	professor	Xiamen University	People's Republic of China
Mr	Male	Xin	Lin	1325591598@qq.com	student	Xiamen University	People's Republic of China
Dr	Male	Takao	Ikeda	ikeda@tky.ieej.or.jp	Senior Economist	METI	Japan
Mr	Male	Alexey	KABALINS	alexey.kabalinskiy@aperc.ieej.or.jp	Researcher	APERC	Japan
Dr	Male	Shin-Hang	Lo	henrylo@itri.org.tw	Manager	Industrial Technology and Research Institute	Chinese Taipei
Dr	Male	Wen-Ruey	Chang	wrchang@itri.org.tw	Senior Researcher	Industrial Technology and Research Institute	Chinese Taipei
Mr	Male	DINH DUY	PHONG	DUYPHONGEVN@GMAIL.COM; PHONGDD@MOIT.GOV.VN	official	ELECTRICYTY AND RENEWABLE ENERGY AUTHORITY/MINISTRY OF INDUSTRY AND TRADE	Viet Nam
Ms	Female	NGUYEN THI TUYET	MAI	MAINTT@MOIT.GOV.VN	official	REGULATORY AUTHORITY OF VIET NAM/MINISTRY OF INDUSTRY AND TRADE VIET NAM	Viet Nam

Workshop Agenda:

APEC Off Grid Electrification Option for Remote Regions in APEC Economies

10 September 2018, Chiang Mai, Thailand

Day 1:				
8:30 AM	-	9:00 AM	Arrival & Registration	
9:00 AM	-	9:15 AM	Welcome	Munlika Sompranon DEDE Thailand
9:15 AM	-	9:30 AM	Opening Remarks	Fengyan Zhang China
9:30 AM	-	10:00 AM	PEA Mircrogrid for Remote Area Electrification: Study at Ban Khun Pae, ChiangMai Province	Titti Saksornchai, Thaila
10:00 AM	-	10:30 AM	DC Microgrid systems and it is applications for o remote regions*	Worajit Setthapun, Thail
10:30 AM	-	10:45 AM	Coffee Break	
10:45 AM	-	11:15 AM	A university-industry driven off-grid solar proje remote community in Malaysia	Gan Chin Kim, Malaysia
11:15 AM	-	11:45 AM	Sarawak Alternative Rural Electrification Sc Providing electricity to off-grid communities in Sarav	Christopher Wesley Malaysia
11:45 AM	-	12:15 AM	Current electrification status in Viet Nam	Dinh Duy Phong Viet Nam
12:30 PM	-	1:30 PM	Lunch	
1:30 PM	-	2:00 PM	An case study for providing electricity using microg a remote island in China*	Xin Lin China
2:00 PM	-	2:30 PM	Applications of Modern Microgrids for Off Electrification	Cary Bloyd, USA
2:30 PM	-	3:00 PM	The microgrid project in Hawaii and its applicatio remote off grid regions*	Leon R. Roose, USA
3:00 PM	-	3:30 PM	Off grid electrification in Australia and the F region ,Project Experiences and Lessons Learned	Paul Rodden, Australia
3:30 PM	-	4:00 PM	Outcome of smart community demonstration proj Japan*	Takao Ikeda Japan
4:00 PM	-	4：30 PM	Coffee Break	
4:30 PM	-	5：30 PM	Group Discussion	All
5:30 PM	-	5：45 PM	Day 1 Conclusion	Fengyan Zhang

Summary of the Presentations:

The workshop started with the welcome remark from Ms Munlika Sompranon, who works at DEDE Thailand and also is the EWG representative of Thailand. She and her team have done a wonderful job to assist on the administrative works and lead to the successful workshop. Next talk is from Professor Fengyan Zhang from Xiamen University, who is the contractor of the project and has lead the team completed the three on-site visits and organized the workshop. She has given an introduction about the project and summary report on the difficulties they encountered during the on-site visits and also the problems that facing the electrification in remote off grid region in APEC economies.

The first presentation is from Dr Titti Saksornchai, who is Head of Renewable Energy and Energy Efficiency Promotion Department, at Engineering and Planning Division for PEA District 1, Chiang Mai, Thailand. The presentation title is “PEA Microgrid for remote area electrification, Case study at ban khun pae, chiang-mai province” Their Micro grid development including: Research and development of new technology; Improve system reliability and quality of supply; Power loss reduction; Utilize local energy resource and green energy. The summary of their work are: Need to find solution for areas that distribution line construction is not possible or not allowed by law; Local community feed back & acceptance are very important; Need to considering system growth at the initial design stage; Micro grid is a practical way to improve system reliability for remote area.

The second presentation is from Dr Worajit Setthapun, who is professor and Dean at Chiang Mai Rajabhat University. Her presentation title is “DC Microgrid systems and it is applications for Off-Grid Remote Regions – Case Study: Chiang Mai World Green City”. Their Smart Community Concept is “Renewable Energy and Green Technology for Local Community”, which including Integrate with Community Resources - Ways of Living; Sufficiency Economy + Green Technologies (RE & EE); Smart Grid as Infrastructure for Green Community Development. In their project they have integrated a DC Microgrid. Their conclusion about advantage and disadvantage of using DC microgrid are: DC Microgrid is possible for decentralized power application; Must educate users because of concern about safety; Must be cautious about electrical appliances to be DC compatible; DC microgrid should be used for lightings and mounted appliances; Must used plugs for DC to prevent Arc; The remaining problem are how can DC microgrid be integrated with AC microgrid? The summarized important factors for a successful remote regions electrification including: Appropriate Technology; Monitoring and Optimization; Integration with Social Development and Economic Development; Create awareness and Share best practices; Demonstrations Sites development and Community Implementation.

The third presentation is from Dr Gan Chin Kim, he is associate professor from University Teknikal Malaysia Melaka (UTeM), Malaysia. The presentation title is “A university-industry driven off-grid solar project for remote community in Malaysia”. He introduced the lesson learned from Kampung Tual project that includes: Many such projects were awarded mainly based on *one-off* basic without maintenance contract; Fit-and-forget approach; Poor ‘*after-sales service*’; Remote system monitoring is a challenge, requires satellite internet connectivity; Lack of holistic system level network for planning, design, operation and maintenance for long term sustainable development. Their move forward goal including: Development of options portfolio for sustainable rural electrification; Systems modelling of power systems resilience to natural hazards; integrating sustainable and resilient planning under uncertainty considering the role of communities.

The forth presentation is from Mr. Christopher Wesley Ajan, who is Manager of Renewable Energy Division at Sarawak company, Malaysia. His presentation title is “Sarawak Alternative Rural Electrification Scheme. Providing electricity to off-grid communities in Sarawak” He introduced the current electrification status in Malaysia, and SARES efforts on Implementation off grid solar system, which including: 1)Timely project delivery and maintain the overall cost within budget in order to reach out as many villages as possible; 2) Develop local competency and capability in solar that are required to ensure sustainability of the programme; 3) Involve local communities in project implementation so that they can draw some benefits from project execution.

The fifth presentation is from Mr Dinh Duy Phong, he is government official of ELECTRICYTY AND RENEWABLE ENERGY AUTHORITY/MINISTRY OF INDUSTRY AND TRADE in Viet Nam. His presentation title is “Current Status of Electrification in Viet Nam” he introduced the Current Status of Rural Electrification in Viet Nam has reached 98% at 2018; but National Power System only supplied to cities and industry areas, In Rural area the grid only supplied the power to pump station of agriculture; The remaining off grid households mostly from mountainous areas and islands terrain; Transportation and installation are difficulties; Investment’s cost is high. The main challenge of electrification for remote regions including: Electricity consumption in rural areas are very small; Most of rural power projects are not economically feasible, which has hindered the investment process; Viet Nam have just removed from the list of poor countries, so it is very difficult to access preferential loans.

The sixth presentation is from Mr. Lin Xin, who is student from Xiamen University, China. His presentation title is: “Investigation on the Application of Micro-grid as Power Supply for Remote Island--Based on the Micro-grid on Dongfushan Island”. The lesson learned from the on –site visit to Dong Fu Shan island microgrid is: Weather and harsh environment could be very difficult for electrify remote regions in terms of installation, transportation, and future maintenance. Therefore using quality products is critical, but that will add more on the cost. Battery needs to be carefully reviewed for the life span (lead acid has short life span) and safety (Li ion battery has safety concern, etc); long term plan has to be addressed at the beginning of the project, especially for securing the maintenance spending resources and assign the responsible maintenance party.

The seventh presentation is from Dr Cary Bloyd, his presentation title is “Applications of Modern Microgrids for Off Grid Electrification” he discussed Alaska Microgrid Partnership (AMP) which is the project to create a development pathway for islanded microgrids and to reduce imported energy by at least 50%. The economical advantages for these microgrids are: 1) Chefornak Mini-grid Business Case: Proposed system 800 kW wind turbines, 650 kW of electric thermal stoves for energy storage, 300 kW battery storage. The result will be able to cut the Cost of electricity from $0.407/kWh to $0.308/kWh and fuel consumption could be reduced by 80% (103,000 gal). 2) Kokhanok Mini-grid Business Case: 2 Vestas 17 (90 kW) wind turbines; 125 kW of electric thermal stoves for energy storage; 120 kW battery storage. This will result Cost reduction from $0.69/kWh to $0.39/kWh and fuel consumption could be reduced by 69% (22,000 gal); 3) Shungnak Mini-grid Business Case: 500 kW wind turbine; 46 kW of electric thermal stoves for energy storage; 100 kW solar photovoltaic. Cost of electricity could decline from $0.632/kWh to $0.548/kWh; fuel consumption could be reduced by 74% (96,000 gal).

The eighth presentation is from Dr Leon R. Roose, his presentation title is “Renewable Energy Transition of Island Grids in Hawaii: Applications for Remote Off Grid Regions” he discussed The increase in PV generation has increased the need for new solutions to reduce the impact of potential cascading loss of generation on the island because of : All utilities are subject to unplanned events such as sudden loss of generation or transmission line interruptions; The impact of these events is more significant on smaller, isolated grids; Most events can be managed by adjusting other generation resources; If the event is more significant, customer loads are automatically disconnected by the utility (at the feeder level), reducing power demand, to try to maintain generation-load balance and stable operation. While events can happen at any time of the day, significant events during the daytime can cause some or all PV on the island to stop operating (disconnect), which increasing the risks on the entire grid. Their solution for stabilize the microgrid includes installing a central battery energy storage system (BESS), which has very high speed response; The BESS can significantly reduces the risk of customer load shedding and improves power quality; Does not take up room on the system when not needed, allowing for the addition of more renewable energy; Can be implemented relatively quickly; Easier maintenance versus a highly distributed customer sited BESS approach (modular battery units can be replaced when needed over time).

The ninth presentation is from Mr Paul Rodden, who is Senior Project Manager at in Ekistica Australia, the title is “Off Grid Electrification in Australia and the Pacific Region, Project Experiences and Lessons Learned” He discussed the best practice for successful electricity generation for remote regions depend on the following factors: Thoroughly determine the energy service to be delivered; Required scale of power system; Available energy resources; Available technology; Accessibility of site (road, sea, seasonal impacts); The nature of the load (load profile); Power requirements (availability, reliability, quality etc); Regulatory requirements; Capacity of individuals and organization to design, install, operate and maintain system; and System finances. All above factors needs to be understood and managed over the whole project life cycle. He also discussed the structural barriers to Off Grid Electrification in Remote Areas, which including 1) Governance: Stakeholder engagement, Capacity building, Support and oversight. 2) Finance： Sourcing finance; required for system life cycle; Perceived risk leads to capital constraints. 3) Supply chain: Design and hardware requirements needs appropriate to context, reliability, Scalability and Modularity, Serviceability, and Portability. And Effective supply chain are critical, also Standardization of technology is important enabler. Lesson learned for successful program critical elements includes: Effective community engagement and capacity building; Ensuring quality components and installation; Demand side management; Ongoing operation and maintenance; Commitment to ongoing funding for O&M; Building installer, maintainer, support agency capacity; Must take the long view and plan and implement for system life cycle. Other important lessens: Risk has cost. Requirement to work through cyclone season increased costs; Land access can be a major problem; Additional project costs in upgrading existing enabling infrastructure; Governance issue remain a concern: Recommended tariff structures not adhered to; Long term maintenance program not locked in; Lack of capacity building impacts local ability to manage.

The tenth presentation is from Dr Takao Ikeda, who is Senior Economist from The institute of energy economies, Japan. His presentation title is "Microgrid system: Energy management and storage in Japan". He introduced the four microgrid projects for islands in Japan that including Okinawa, Oki, Koshiki, and Miyako islands. And also the demonstration project in Maui, Hawaii. They have achieved effective usage of surplus renewable electricity by shift of charge timing (peakshift), by using frequency control by demand side load management, and alleviation of voltage rise in lower distribution network. They also acknowledged that increasing EVs and chargers are necessary for the “Duck curve” countermeasure.

At the end of the workshop, Dr Cary Bloyd has chaired the discussion session, and every attendee shared their thoughts about the achievement of the workshop, lesson they have learned from the workshop and their input about how to achieve electrification in remote off grid regions in APEC economies.

Summary of the Discussion:

Figure 39. Discussion photos of the workshop

Key findings:

1) The project has successfully completed its tasks, and has provided valuable information about Off Grid Electrification Option for Remote Regions in APEC Economies. The presentation of the workshop are very informative and provide valuable advices and lessens for APEC economies to solve their similar problem in their off grid regions.

2） The clean and renewable energy including solar, wind, battery and microgrid technology have reached the stage that are more technology mature and economical affordable than traditional diesel generator to supply electricity to off grid and remote regions.

3） The problem and difficulties to adopt these technologies are actually more due to the off grid regions' hard to reach geographic location, lack of telecommunication availability, ongoing maintenance issue, lack of local residence education and involvement, and lack of continuous maintenance budget supply. Feasible business model for more sustainable way to maintain long term reliable energy supply are needed.

4) The adoption of DC microgrid will facing the same difficulties as mentioned above, further more it is not mature enough yet, so it may not suitable for the remote off grid regions in developing economies because lack of technology support, availability of DC load products, also the spreading and scattering residence. DC microgrid could be a good application for net zero commercial buildings for developed economies by integrating centralized or distributed energy storage unit, also there will be better technology support in the developed economies.

5） This project has successfully collaborated with many international institutes, and also proposed three more new projects to continue research and development on using microgrid technology to provide resilience, reliability, efficient and clean electricity to the remote off grid regions around the world.

Bellow are comments from the attendee:

1) Dr Titti Saksornchai: For small grid connected to main grid: system growth is important, demand

may increase very fast; engaging local community, using local resource, such as water resource, using utility to collect water resource to generate electricity later on; reduce operation and maintenance cost are very important.

2) Dr Worajit Setthapun: Operation and maintenance cost has to be considered at the beginning. Long term plan is necessary. Legal issue with the local residence has to be considered. Policy waiver maybe needed. Training community leader can help the success: flexibility of the system is also important to integrate different RE sources in the future. Demand side consideration
3) Dr Gan Chin Kim: Government needs to avoid one-off project, otherwise system may be abandoned in the future. Be clear on policies regarding these types of projects. Electricity generation needs to follow the demand.
4) Mr. Christopher Ajan: Utility company needs to shift the mindset on reluctance for renewable energy. Trade off of grid extension for RE, Learned multiple RE resources can be integrated in to the microgrid. Combining Water energy, telecommunication will be considered for the future microgrid.
5) Mr. Dinh DUY PHONG: O&M is very important, needs to be considered at the beginning of the investment. Building up to certain capacity can help. Responsibility of the system belongs to which party needs to be addressed. Local training can be very challenging.
6) Mr. Lin Xin: The installed system has not reached the point to improve local people living standard due to some difficulties on running it effectively and sustainably. Automatically O&M could help if achievable in the future.
7) Mr. Leon Roose: Prepaid meter could be a good solution in certain cases. Finding local focal point to take ownership of the system, or some kind of local related business could help. Sustainable business model are needed.
8) Dr Paul Rodden: Investment needs to consider the long term. Engagement of the end user on O&M, capacity building will help the O&M, government needs to lead the way.
9) Dr Takao Ikeda: How to deal with excess RE power supply is important to consider. Evening time rapid changes of the backup power supply needs to be considered (Duck Curve). Acceptable ESS is very important.
10) US: Due to the failure of battery, wind, etc, standards are important for product selection, which including the design and Spec of the components.
11) Chinese Taipei: PV value cliff may become a new issue to promotion of renewable energy. We need to take it into consideration for achieving doubling goal of RE share in the APEC regions.
12) Indonesia: It is very important for sharing information for off grid electrification options.
13) Philippines: There are lots of islands need electricity. System failure, O&M issues could hinder the success, local people need to share responsibility. PV and Battery disposals are also important issues in the future,
14) Korea: RE/off grid project needs to be commercial viable project. Government is not going to support forever.
15) Hong Kong, China: off grid system for the islands needs to meet demand side requirement. RE storage needs to be considered.
16) APERC: Isolated system needs to be reliable. Community engagement is important. Fuel switching, such as thermal storage and higher quality component will help the sustainability.

Conclusion：

We have successfully completed on- site investigation at China, Chile and Australia, investigated the local current off grid electrification status, the cost, problem and obstacles of providing electricity to these regions, and evaluated the technology and economical advantages of adopting solar, battery, microgrid and DC microgrid to these regions. The team also promoted the awareness of adopting solar, battery, microgrid and DC microgrid by interviewing and gave out seminars to multiple levels of related parties, such as local residence, energy experts, university scholars and local government representatives. We also successfully organized the one day workshop on Sep 10, 2018. There are total 12 speakers at the workshop and more than 30 attendee attended the workshop. At the end of the workshop, a round table discussion produced valuable summary on common problems encountered to provide electricity to remote off grid regions, such as how to sustaining the efficient electrification supply after the projects are completed, and suggestions on how to solve these problems. Following are the key findings of the project:

1) The project has successfully completed its tasks, and has provided valuable information about Off Grid Electrification Option for Remote Regions in APEC Economies. The presentation of the workshop are very informative and provided valuable advices and lessens for APEC economies to solve their similar problem in their off grid regions.

2）The clean, renewable energy including solar, wind, battery and microgrid technology have reached the stage that are more technology mature and economical affordable than traditional diesel generator to supply electricity to off grid and remote regions.

3）The problem and difficulties to adopt these technologies are actually more due to the off grid regions' hard to reach geographic location, lack of telecommunication availability, ongoing maintenance issue, lack of local residence education and involvement, and lack of continuous maintenance budget supply. Feasible business model for more sustainable way to maintain long term reliable energy supply are needed.

4）The DC microgrid will facing the same difficulties as mentioned above, further more it is not mature enough yet, so it may not suitable for the remote off grid regions in developing economies because lack of technology support, availability of DC load products, also the spreading and scattering residence. DC microgrid could be a good application for net zero commercial buildings by integrating centralized or distributed energy storage unit as the backup energy source and also for stabilizing the microgrid power supply for developed economies, it also has better technology support.

5. The DC microgrid market is still very limited due to the technology is not mature enough, lack of product standards, lack of DC loads products availability, and some safety concerns. Although the 380VDC is recommended by Europe, Japan and US, but other economies such as South East Asia may have their own standards due to their current different AC standards. As discussed before, most of the remote regions are not able to finance the installation and maintenance cost of the microgrid system, so government or financial foundation support such as world bank, Asian bank, private foundations are essential to provide electrification to remote off grid regions.

6. This project has successfully collaborated with many international institutes, and also proposed three more new projects to continue research and development on using microgrid technology to provide resilience, reliability, efficient and clean electricity to the remote off grid regions around the world.