Asia-Pacific
Economic Cooperation

Workshop Report: Long-Term Reliability Study of Photovoltaic (PV) System Installation on Islands

APEC Energy Working Group

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Acknowledgments

The workshop could not have been accomplished without the contributions of many individuals and organizations. We would like to thank all those whose efforts made this overview possible, in particular those names on page two. The project team expresses its gratitude to Mr Jin-Sheng Su, Secretary General of Bureau of Energy, MOEA, Chinese Taipei, who was the Project Overseer. New and Renewable Energy Technologies Expert Group (EGNRET) supported the project from the concept note stage. We also appreciate all assistance in administering the project from APEC Secretariat. A special thanks to Ms Norila Mohd Ali for her fast assistance during the whole implementation period. The team also received her assistance during her vacation period.

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Executive Summary

The workshop was held at the room2B, 51 Bldg. in the Chung Hsing campus of Industrial Technology Research Institute (ITRI), Hsinchu, Chinese Taipei on 9 March and Taipei 101 city tour on 10 March 2017.

There were eight invited speakers to share their experience in the PV-related field. Four of them were APEC-funded speakers, they are Mr Nguyen Duc Cuong, Mr Xie Bingxin, Prof Hisakazu Okamura,and Prof Wen-Lung Lu who from Viet Nam, China, Japan and Chinese Taipei respectively. The rest were self-funded speakers including Mr Rajkumar Thammineni from Hong Kong, China and Ms Ku-Hsiu Hsiung, Ms Joanna Chen and Dr Cheng-Yu Peng from Chinese Taipei. Two of eight speakers are female.

APEC funded two participants per economy. Participants from Thailand, Philippines and Malaysia are government officers. Participants from Viet Nam are private individuals. Two of eight APEC-funded participants are female. For self-funded participants, one from Japan and the rest of thirteen participants from Chinese Taipei. All twenty two participants included five females and seventeen males.

The abstracts of all presentations are listed by session. During the Round Table Discussion and the analysis of the project evaluation survey contents, both participants and speakers are interested in the issues faced or will be faced in the near future. For example, floating PV systems become more popular due to the limited space for installing PV systems. However, the related standards, requirements, and rules to monitor this kind of systems are not ready for all economies. How to recycle and re-use the retired PV systems is an emerging problem in the near future. It seems like APEC economies all start the research and try to solve this problem. Due to the retired PV system will create huge amount of waste and results in the environment burden. Policy for promoting renewable energy was discussed in the Round Table Discussion, all participants eager to learn from each other’s experience and the executed policy. We believed that all participants benefited much from the workshop.

SESSION I: Policy of APEC Economies

Speaker: Ms Ku-Hsiu Hsiung, Chinese Taipei
The PV Policy of Chinese Taipei

1. The PV Policy of Chinese Taipei

Feed-in-Tariff (FIT):

The main purpose is to breakthrough market competition and installation barriers for renewables. A fixed feed-in-tariff mechanism is established for renewable electricity with guaranteed purchase period to ensure the achievement of promotion target.

Tariff rates are set and applied for 20 years. Tariff rates set on the Power Purchase Agreement (PPA) signing date, but Solar PV tariff rates are set on date when generating equipment installations are completed.

Installation with high-efficiency modules will get extra 6% plus on the rate.

FIT for PV in 2017			
Type	**Capacity (kW)**	**2017 price (US¢/kWh)**	**2017 high-efficiency modules (US¢/kWh)**
Roof	≧1 ~ <20	19.38	20.54
	≧ 20 ~ < 100	15.80	16.75
	≧ 100 ~ < 500	14.41	15.27
	≧ 500	14.00	14.84
Ground	≧1	14.43	15.30
Floating type	≧1	15.68	16.62

Installation locating in northern-Chinese Taipei (Taipei, Keelung, Taoyuan, Hsinchu, Miaoli, Yilan, Hualien) or offshore islands will get extra 15% plus on the rate.

2. The PVs Promotion Target and the Current State of Solar Power

The Bureau of Energy (BOE) of the Ministry of Economic Affairs (MOEA) has laid out a plan that the accumulated PV installed amount reach 20GW by 2025 to achieve the goal of a nuclear-free island. The PVs promotion conducts two main missions: (A) Foster PV-friendly environment in Chinese Taipei; (B)Assist government institutions and industries in increasing PV installed capacity to 20GW by 2025, including 3GW of roof-top PV installations and 17GW of ground-mounted PV installations. Led to a total investment of NT $ 1.2 trillion and create 100,000 jobs.

Two-year Photovoltaic Promotion Project

The Bureau of Energy has deploying “Two-year Photovoltaic Promotion Project”. The project aims to install 1.52GW of solar energy within two years, including 910 MW of rooftop and 610MW of ground-mounted PV installations.

Four main categories of rooftop systems: public buildings, factories, agricultural facilities, and other buildings. The target capacity for rooftop PV systems is 910MW
Four main categories of ground-mounted systems: salt industry lands, severe land subsidence zones, inland waters, and landfills. The target capacity for ground-mounted PV systems is 610MW

Speaker: Mr Rajkumar Thammineni, Hong Kong, China

Financing of PV investments and the role played by active asset managers

The presentation provides an overview of key characteristics of Asian Infrastructure, and the role played by active asset managers in financing and developing Asian infrastructure. The presentation also introduces an investment strategy for Asian infrastructure, with key considerations and examples set out to illustrate the execution of the strategy.

Governed by long term contracts and defined regulatory structures, infrastructure assets have traditionally been favored by institutional investors (e.g. pension fund, sovereign wealth funds). While OECD infrastructure has typically been classified as stable yield generating investments with moderate risk, Asian infrastructure, however, is in its expansion phase. Consequently, Asian infrastructure investments are expected to yield greater capital growth opportunities but with higher risks when compared to OECD infrastructure.

On one hand, asset managers provide growth capital to the infrastructure developers and operators. On the other hand, asset managers deliver returns to its institutional investors by enhancing the value of the asset. As such, there are three crucial key components when investing in infrastructure to yield attractive risk-adjusted returns: buy right, improve operations, and multiple expansions.

To buy right, rigorous underwriting, including in-depth analysis, documentation and financial modelling, will be carried out. Thorough due diligence on the market, regulatory environment, company and analysis on key risks and mitigates will be conducted prior to an investment. Post investment, asset managers will aim to create value-add through improved operations, MIS and controls upgrade and business hygiene implementations. Asset managers may aim to further enhance the value of the company by de-risking and transforming the investment from a single asset into a platform, through roll-up strategies to capitalize on synergies arising from economies of scale and scope.

Speaker: Mr Nguyen Duc Cuong, Viet Nam
The PV Development Target and Policy of Viet Nam

The content of the presentation consists of four main parts, namely: i) Economy power mix – past trends and in 2016; ii) RE and PV development target & key policies; iii) Main barriers; and iv) Summaries.

In the past 10 years, Viet Nam's electricity capacity has increased 3.4 times from 12.5GW in 2007 to 42GW in 2016. Viet Nam's power generation infrastructure includes coal, oil &gas, hydropower and renewable powers. However, the proportion of renewable power capacity is still too small compared to the potentials. Renewable electricity accounted for only about 6% in 2015. Meanwhile, thermal power (coal, oil & gas) accounts for over 55%. In order to secure power supply, reduce coal imports, fossil fuel consumption, and GHG emissions, the Government of Viet Nam is attempting to diversify the national energy supply through the development of RE/Solar PV. South

Two main policies on RE was issued in 2015 and 2016 for implementations. Those are: i) National Strategy for RE Development; ii) and National Power Development Master Plan. The targets of two polices are to increase the share of electricity generated from RE. The electricity produced from the PV shall increase from around 10 million kWh in 2015 to 1.4 billion kWh by 2020; 35.4 billion kWh in 2030 and around 210 billion kWh by 2050. To encourage & support for RE and PV development, the policy mechanisms such as electricity price (FIT) & investment assurance; Renewable Portfolio Standard – RPS; Net-metering, and tax incentives (import tax; corporate income tax, etc.) have been issued and are being finalized.

However, to develop PV in Viet Nam as targets mentioned in two main policies, the identified barriers need to be removed early. Those are: i). Institutional strengthen; ii). Market formulation; tariff mechanisms; and environment taxes.

The final part of the presentation refers to the summary on RE/PV potential and the clear messages of Government to the development of solar energy sources, especially PV powers in specific targets.

Speaker: Mr Xie Bingxin, China
The PV Policy of China

The speech cover two sections; first section discuss about China PV industry current status, second section discuss about the China PV policy and future trend.

China becomes world's largest accumulated PV installation area after more than ten years developing. China accumulated installation reach 78GW at 2016. The PV manufacturing capabilities and PV technologies is keeping expansion an advancing respectively. The Polysilicon、wafer、cell、and modules are increase more than 17.6%、31%、19.5%、and 15.7% respectively. The world's largest PV manufacturing capability is last ten years. The Polysilicon and PERC single crystal solar cell efficiency reach 18.6-19.2% and 20.5-20.8% respectively. The electric power price decrease to 0.65、0.75 和 0.85 RMB per Kw/hour under third type sunshine area due to the technology advancing and scandalized/economic scale mass production.

The healthy development of China PV industry is inseparable with China PV policy. Renewable Energy Law is on the top of China PV essential policy, which provides China PV Industrial development legal protection and has a guiding significance. The 13th Five-Year Plan for PV medium and long term development is made under the base of the law. The plan offers guide and basis for China to reach 110GW accumulated PV installation. 《Instruction on establishing target guidance system of renewable development and application》and 《Notice of Trial implementation of Renewable Energy Certifications issue and initiative subscription deal system》offer the implementation of renewable energy quota system foundation. 《Frontrunner Plan》、《PV poverty alleviation》、and 《Distributed PV——micro grid》 plans are complement each other. The plans also promote technologies advance、application of distributed PV、and social benefits at the same time. The mentioned three plans are the major themes of 13th Five-Year Plan. Certainly, China will make new plan/policy according to the PV industry new development situation and development requirements to make sure that China will reach Non-fossil energy consumption accounted for 15% of the primary energy consumption ratio.

SESSION II: Technologies and Case Study
Speaker: Prof Hisakazu Okamura, Japan
Stream of Distributed Energy and Challenges in Japan

Through my experience of working for IBM Japan as leader of Smartcity, I led several smartcity projects domestically and internationally. The smartcity project sounds city project that is far from PV or energy, however the fact is that over 340 projects out of 608 large smartcity projects are energy related and over 45% of them are in Asia now. One of my PV work was the Setouchi PV plant that is the largest PV plant in Japan with $1.1 B 230MWh. In early stage of the smartcity projects in Japan started from energy especially PV implementation due to Feed in tariff. In 2011, the great earthquakes happened. It was another strong trigger of dragging the PV project all over the economy, because 52 out of 54 nuclear plant were shut down after the Fukushima explosion.

5.6GW before FIT and 20.8GW after FIT, totally 26.3GW PV were installed as of 2015 end, out of 42.2GW renewable energy installed. As FIT price went down from 40 to 24 yen now, over 10kw sized plants' booming number is decreasing but we consider the linear increase continues beyond 2030.
Under this circumstances, distributed energy is in focus recently. Due to the great earthquake happed in 2011, volcanos and plates in Japan are activated. Not connected big power plants but small independent power sources are getting considered for the disaster preparation.

Several new technologies are also coming up. "Mountain solar" that is PV panels but structured like M character to receive the sun light more hours with half sized land for significant efficiency. "Volter40" the gasification machine that generate 40KWh power and 100 kwh heat with only 5m long package that contains a gasification module and an engine inside. In order to consider the sustainability seriously, the new maintenance service named "Eyeeco" with very low price are getting very popular now. This is far from existing western type remote monitoring. Insurance companies, maintenance companies and IT remote monitoring companies are collaborating for this service to spread the sustainable PV plant operation in Japan.
Decrease of FIT price, disaster prevention, generation efficiency, and sustainable plants, distribution energy and those latest technologies and new services are the stream and the challenge in Japan now.

Speaker: Ms Joanna Chen, Chinese Taipei
Case Study on Hybrid Mini-Grid Application – The Philippines

The Philippines is composed of over 7,000 islands. Power infrastructure development is focused on three main islands: Luzon, Visayas and Mindanao. About 30% of rural households are located in several hundreds of small islands, which are not connected to the national transmission grid. The power demand in these remote islands are currently supplied by diesel power plants operated by National Power Corporation (NPC). Due to difficulties in fuel transportation and high fuel prices, cost of energy in remote islands ranges from U$ 0.7/kWh to more than U$ 1.0/kWh and power supply hours are low.

NPC operated almost 300 diesel power plants in 2014. Due to high operational costs, only 28 provided 24/7 electricity services, 70% of the power plants provided electricity services less than 8 hours per day. The electrification ratio of the whole economy in 2014 in 80.9%. There are around 4 million households without electricity access. The mission of NPC is to provide 24/7 reliable supply of electricity in all islands. Due to high power generation cost, local subsidized electricity sales cannot cover the true cost of energy production. To lower government subsidies and provide reliable supply of electricity, NPC is studying the feasibility of substituting pure diesel systems with PV-diesel hybrid power plants.

ITRI was commissioned by NPC in 2016 to evaluate a set of islands in northern Philippines. A simulation analysis was done on the islands, the analysis focuses on the relationship of the RE capacity, battery capacity, fuel saving effect, RE excess energy percentage using the Homer Energy software.

The Mini-Grid solutions for the 3 islands Island B, Island I and Island S still use diesel genset as the main source of power, and use renewable energy as complementary power in order to reduce fuel consumption. Assuming there is no shading of PV, and diesel genset runs at 25% baseload, Homer analysis results show that the fuel saving effect and excess RE of hybrid systems varies with different PV and storage installed capacity. With more PV capacity installed, fuel saving is more apparent, however there is also more excess RE. With an addition of a storage system, excess RE could be saved for later use. However, for a more detailed assessment, component costs and business model should also be considered.

Speaker: Dr Cheng-Yu Peng, Chinese Taipei
Long-Term Reliability Study of PV Systems for Installation on Islands

The studied PV system is installed at the third floor of the Construction Bureau of Penghu County Government at June, 1999. The aging PV system was operated for seventeen years under harsh environment, high humidity and high salt environment.

Avoid Potential corrosion

It is found that the main issue, which damage the long term reliability of the system is potential corrosion phenomena. Although the system's parts was maintained / replaced on December, 2007 to resume the power output, plastic spacers were used between Aluminum frame and stainless screw to avoid potential corrosion problem. The mentioned action is not really solve the potential corrosion problem. It is suspect that the sea wind and rain with salt accumulate in the Aluminum frame and screw. The accumulated salt becomes conductive and then generate potential corrosion problems between Aluminum frame and screw. It is suggested that for new Aluminum frame, pre-drilled holes should be processed and then go through anodic treatment later. On the other word, all pre-drilled holes have anodic treatment.

Improve diode burn out strategy

It is a necessary connection between wider Ribbons due to the connection structure of aging module. Tin/Lead wire is used to reinforce the strength of Ribbon connection. Expansion caused by heat and contraction caused by cold is the root cause of the poor connection between wider Ribbon. The chosen diode should pass the Bypass diode thermal test of IEC61215ed.2.

Improve wider Ribbon shedding strategy

Tin/Lead wire should be used to reinforce the strength of Ribbon connection. The reinforced connection point therefore can stand expansion caused by heat and contraction caused by cold cycles.

Speaker: Prof Wen-Lung Lu, Chinese Taipei
Construction and Case Study of Robust Photovoltaic Monitoring System

This report presents the construction and case study of robust photovoltaic monitoring system. First introduce the purpose of the monitoring system, explain the performance indicators of PV system and how to build a robust PV monitoring system. Then, the daily equivalent daylight hours(Peak Sun Hours, PHS) from the monitoring system which built in Yunlin, Tainan and Kaohsiung areas was used to evaluate the application of monitoring data to future power dispatching. Finally, through the construction of high efficiency passivated emitter rear cell (PERC) and heterojunction technology (HJT) photovoltaic power generation system built by the Chien-Hsin University, according to performance ratio (PR) and array ratio (RA) value to compare its performance. Verification in the high irradiance, because the HJT has a lower temperature coefficient, so the power generation system is also better, but in low irradiance conditions, PERC has a better output performance.

As stated in this report, the robust photovoltaic monitoring system can be used as PV system performance evaluation, reference for purchase rate parameters of photovoltaic generation power, forecast of power generation of photovoltaic generation system and renewable energy forecasting used in power dispatching.

Round Table Discussion

Q:

Chinese Taipei Ms Rainy Hsiung:

What are the standards and requirements for floating PV technology in China?

A:

China Mr Xie Bingxin:

The IEC has standardized some floating PV installation steps, but certain certifications are still under discussion. Criteria such as anti-dust or water-resistance need to be included. Material requirements and specifications of floating PV are most difficult to standardize, particularly for the interconnectors between boys to stabilize the system, due to the PV industry's inexperience in such technology. China is expected to come up with standards for floating PV in the next half of 2017.

Q:

Philippines Mr Ronaldo T. Angeles:

Currently in China, the RE Law is administered by the NEA, but RE pricing and other regulations are overseen by other agencies. What are the plans regarding the combining of management of RE industry regulations?

A:

China Mr Xie Bingxin:

The NEA is a lower level government agency in contrast with other Ministries, so it is very difficult for NEA to have strong control over all facets of the RE Law. There is talk about establishing a Ministry of Energy to combine the management of all RE regulations under the new ministry, however this is still a long term goal. Fortunately, the RE Law is highly supported by the prime minister of China, so there are no problems in administering the Law.

Q:

Malaysia Ms Mdm Suhana Shamshudin:

Do China and Chinese Taipei have policies or procedures to handle the recycling and disposal of RE system materials after system failure?

A:

China Mr Xie Bingxin:

Research is still ongoing.

Chinese Taipei Ms Rainy Hsiung:
Chinese Taipei produce mostly modules, so ITRI has project with government to research on waste recycling of RE systems, and will share related information after conclusion of project.

Japan Prof Hisakazu Okamura:
There are professional agencies in Japan that deal with such processes. A recycling contract must be signed with a professional disposal agency when the system is initially installed. In japan, not just PV, but also other electronic and home appliances need to be recycled properly. Recycling cost is also considered in the original purchasing contract of large appliances. The recycle technology detail is un-known.

Q:
Chinese Taipei Mr Tom Wu:
The total power generation of the United States is 1000GW with 300 million in population, China currently only generates 1600 GW with 1.3 billion people in population, so apparently China's power consumption still have much room to grow. To reach the national goal of 15% RE generation by 2020, China needs to generate 600GW from RE, is this possible?
A:
China Mr Xie Bingxin:
In China, RE includes hydro and nuclear. We have reached 12% RE generation by 2015. Hopefully solar, wind, biomass/biogas could have larger percentage in future RE generation.

Q:
Thailand Mr Warote Chaintarawong:
Can Prof Okamura discuss more about home Energy storage system?

A:
Japan Prof Hisakazu Okamura:
A company of Tokyo University produced a huge sized but very rapid storing and discharging battery for power industrial power generator use. That is approved by EPRI. It is to stabilize the out voltage, so the capacity is huge but the duration of holding electricity is just few second. The power generator side storage is one of the

trend now.

Secondary the Tesla home battery will be on the sale from this year for very cheap price like $5,000 US. This may change the market significantly. We didn't think the home battery so seriously due to its high price but it will be a key to change the world.

In 2016 the first liberalization of electricity in Japan started but we still can not store the market electricity and personally generated electricity into one battery. In 2020, the second round allow us to store those into a same volume and use the personally.

Distributed energy popularity is also watching that movement. Small bio gas generator and other system are also needing the suitable size of butteries. I think many small industrial butteries will be on the market so rapidly.

There is an exhibition named Energy storage summit, a symposium organized by German Government around the world. I am helping them for years in Japan and there are many new companies and technologies coming up every year.

Considered the capacity needed to hold the power generated by whichever the huge plants or the small plants, the capacity balance between the generating amount and storing amount. Many projects say it would be around 35% of the whole amount of the generation is the capacity of the battery.

Q:

Japan Prof Hisakazu Okamura:

Why Ms Chen mentioned storage system is so small? The typical energy storage system is about 15% of the output.

Thailand Mr Warote Chaintarawong:

1. Reason why you choose 1600kWh storage for module in Island B (for example), while it can increase more capacity of energy storage for the target of project is saving more fuel. On the other hand, I think this project is interesting that can adapt to off-grid areas not only on the island but also in rural area, should don't forget to think about cost benefit in term of economic which Joanna had already mentioned at the conclusion.

2. For your assumption the number of 25% baseload for running diesel genset, why

you selected at 25%, it maybe some number which the best efficient should be research more detail.

A:

Chinese Taipei Ms Joanna Chen:

The PV/WT/Diesel/Battery hybrid system schematic is as described in the presentation. The rules of operation of the power supply system is as follows: at minimum, the diesel genset must run at baseload (25%). It is the minimum requirement for operating the Diesel power generators. The Diesel power generators also supply the main electric power in the island. The Diesel power generator therefore must be turned on. If the diesel generators are already running at baseload, but potential PV+WT output is higher than needed (load – diesel genset baseload), excess energy generated from PV+WT shall be saved to the storage system and released to the load whenever needed. If the storage system is fully charged, output from PV and/or WT must decrease to ensure overall power system stability. On the other word, the storage system is just to maintain the ramp rate pf total power supply system. It is designed to maintain the stability of overall power supply.

Q:

Philippines Mr Ronaldo T. Angeles:

How is RE forecasting technology used in Chinese Taipei right now? In Philippines there are large PV generation systems in one single area, which impacts the stability of the utility grid. So forecasting is more immediate issue for us instead of battery technology, since battery storage is still very expensive.

A:

Chinese Taipei Tom Wu:

Taipower provides very good electricity supply service for Chinese Taipei, so right now we do not need RE management problems, but if more RE power is connected on-grid, then more studies must be done.

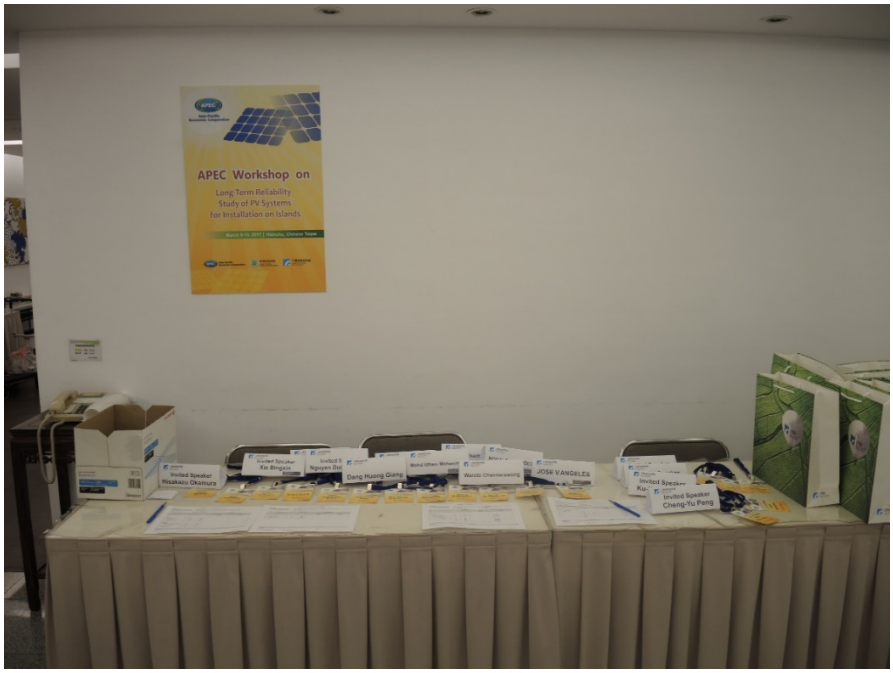
Chinese Taipei Prof Lu:

Until now, Chinese Taipei only has 1.2GW PV energy installed, so the impact on the grid system is minimal, if PV energy grows larger then we will face some problems in the future.

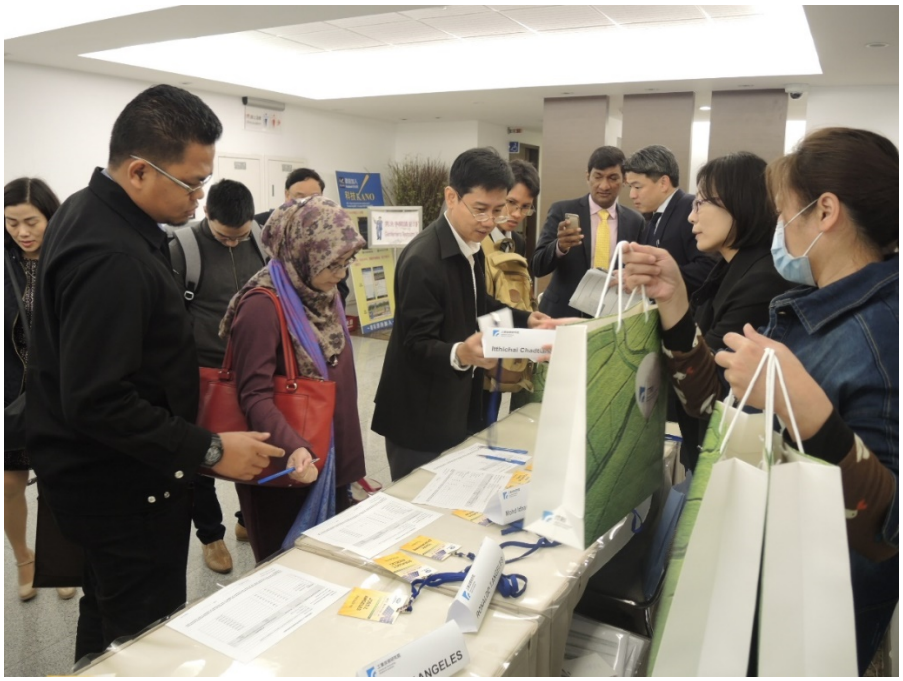
Workshop Agenda:

Day 1: Thursday, 9 March, 2017		
09:30-09:45	Registration	
09:45-09:55	Welcome Addresses	Chinese Taipei
09:55-10:00	Group photo	All APEC invited people
SESSION I: Policy of APEC economics		
10:00-10:30	The PV Policy of Chinese Taipei	Ms Ku-Hsiu Hsiung Chinese Taipei
10:30-11:00	Financing of PV investments The role of asset management companies	Mr Rajkumar Thammineni Hong Kong, China
11:00-11:30	Coffee Break	
11:30-12:00	The PV Development Target and Policy of Viet Nam	Mr Nguyen Duc Cuong Viet Nam
12:00-13:00	Lunch Break	
13:00-14:00	The PV Policy of China	Mr Xie Bingxin China
SESSION II: Technologies and Case Study		
14:00-14:30	Stream of Distributed energy and challenges in Japan	Prof Hisakazu Okamura Japan
14:30-15:00	Case Study on Hybrid Mini-Grid Application - Philippines	Ms. Joanna Chen Chinese, Taipei
15:00-15:30	Coffee Break	
15:30-14:00	Long-Term Reliability Study of PV Systems for Installation on Islands	Mr/Dr Cheng-Yu Peng Chinese Taipei
16:00-16:30	Construction and Case Study of Robust Photovoltaic Monitoring System	Prof Wen-Lung Lu Chinese Taipei
16:30-17:30	Round Table Discussion	All Delegates
16:30-16:40	Wrap-Up and Next Actions	Chinese Taipei
16:40	Adjourn	
Day 2: Friday, 10 March 2017		
Site Visit	City tour (Taipei 101) in Chinese, Taipei **(Invited only)**	

Workshop Photos



Registration



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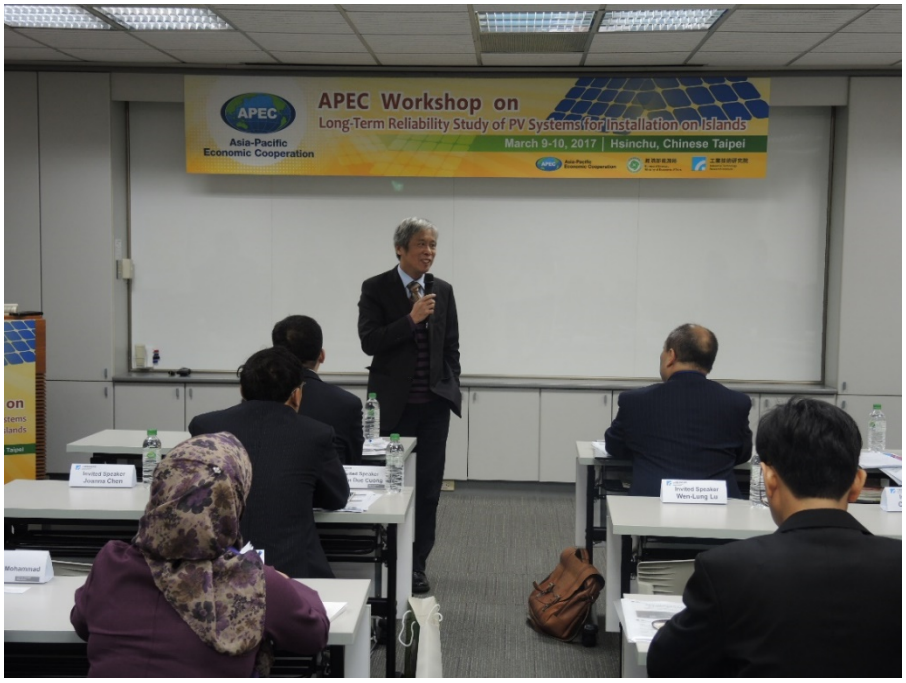
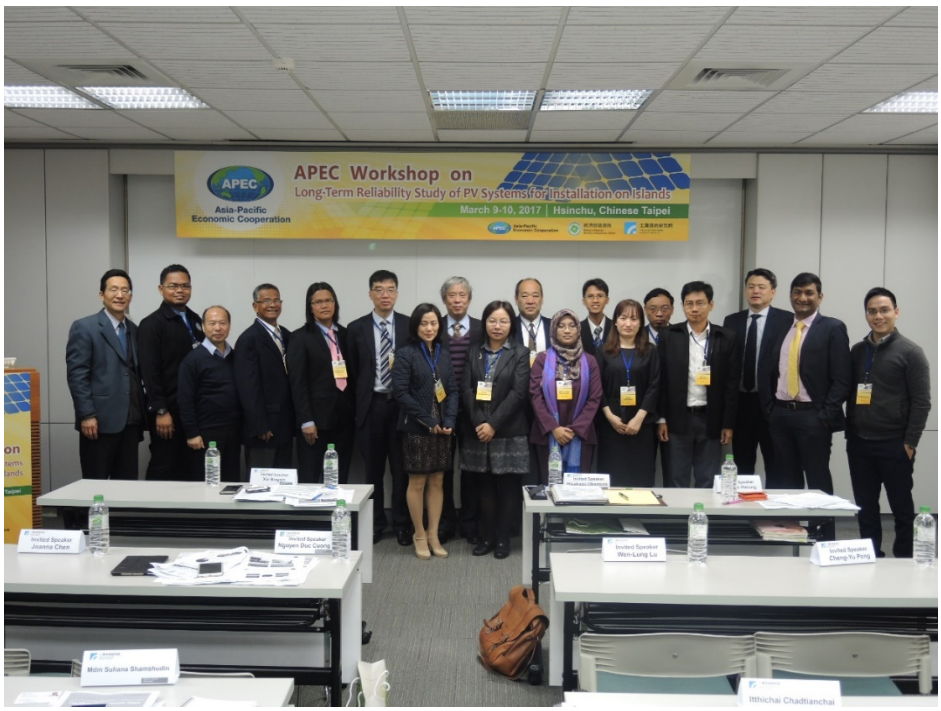
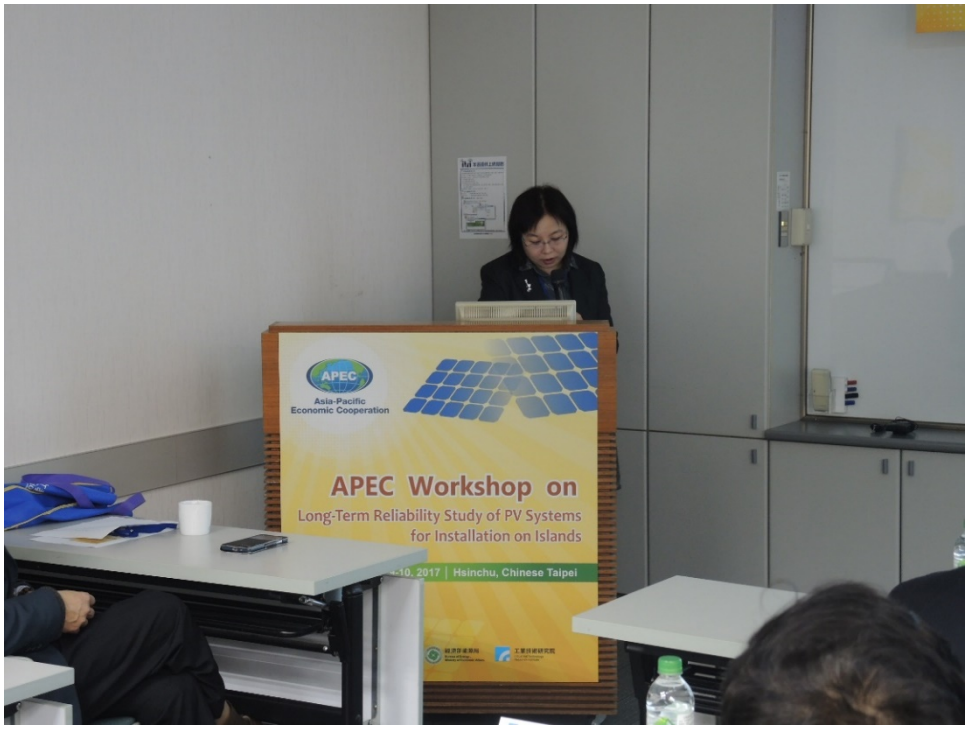


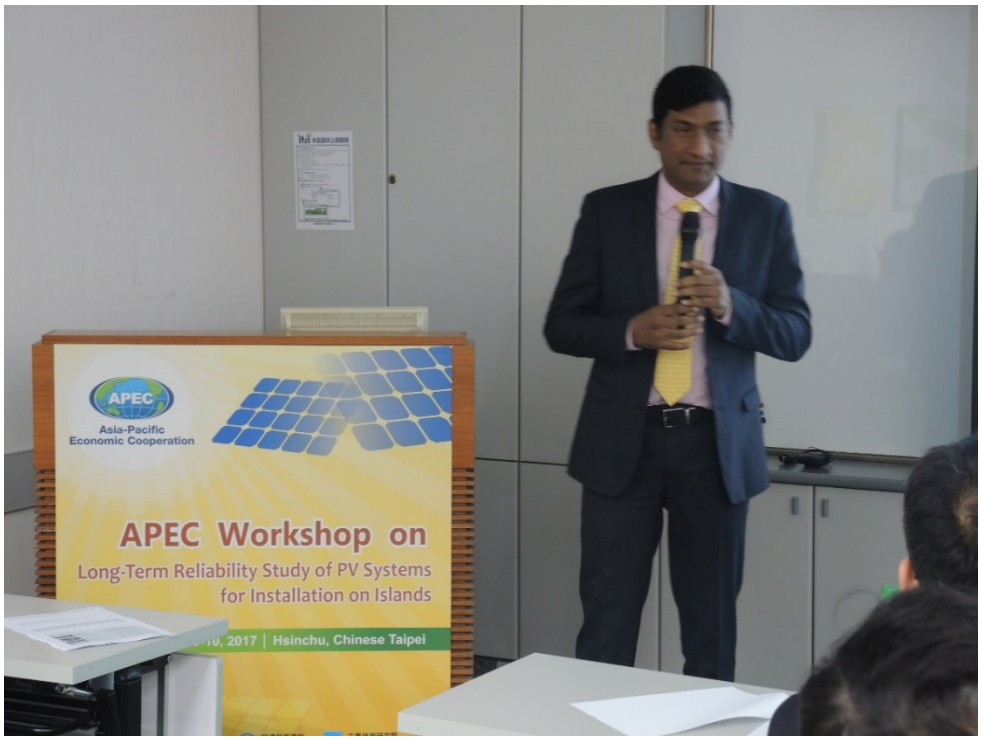
Welcome Addresses – Dr Bing-Chwen Yang, Deputy General Director/ITRI



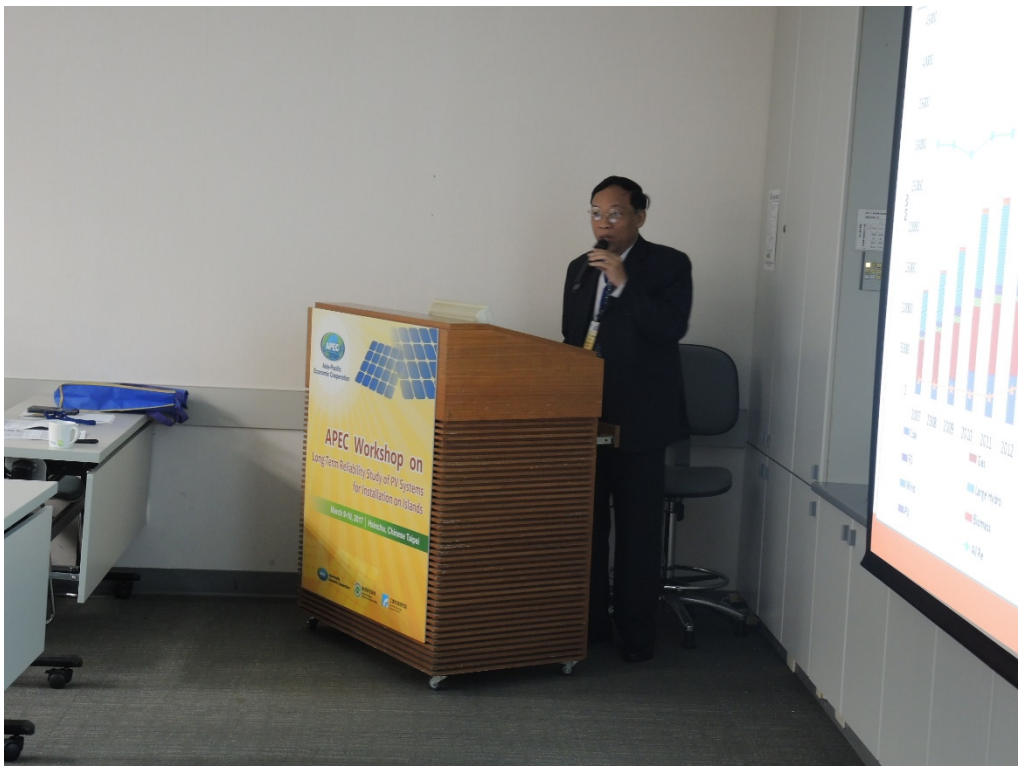
Group Photo



Speaker: Ms Ku-Hsiu Hsiung, Chinese Taipei



Speaker: Mr Rajkumar Thammineni, Hong Kong, China



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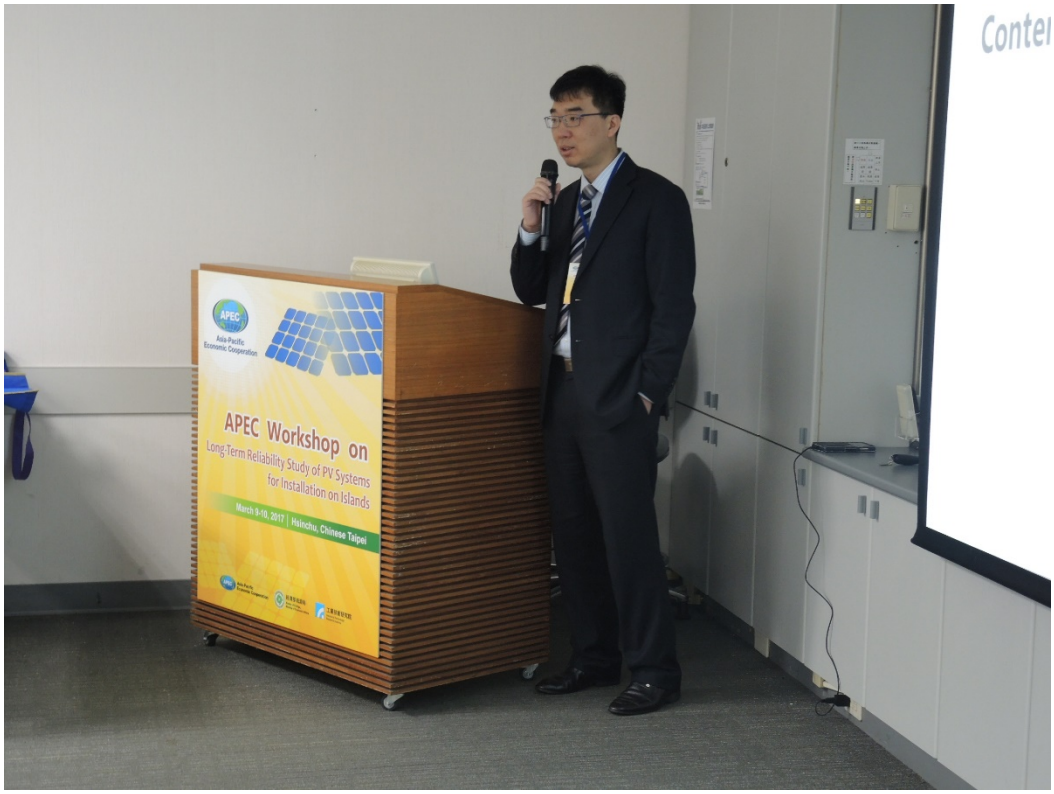

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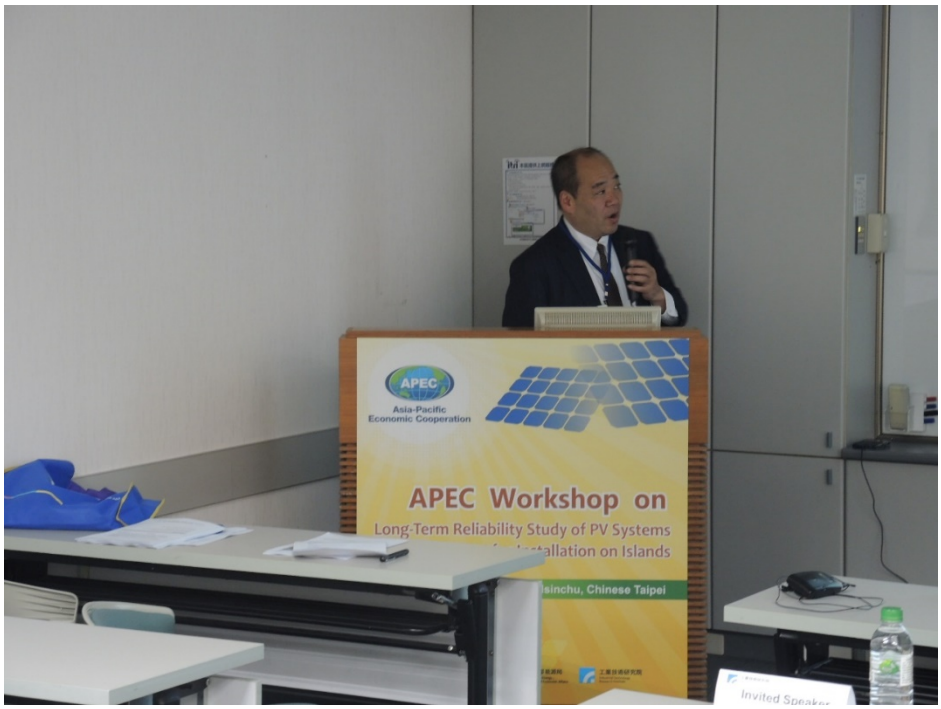
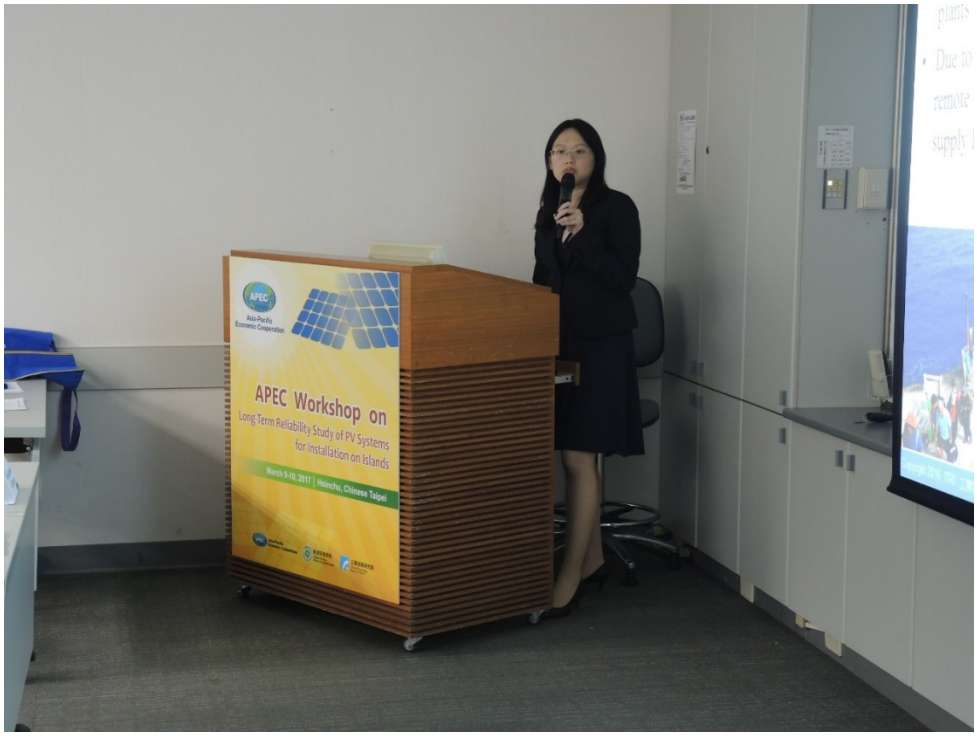
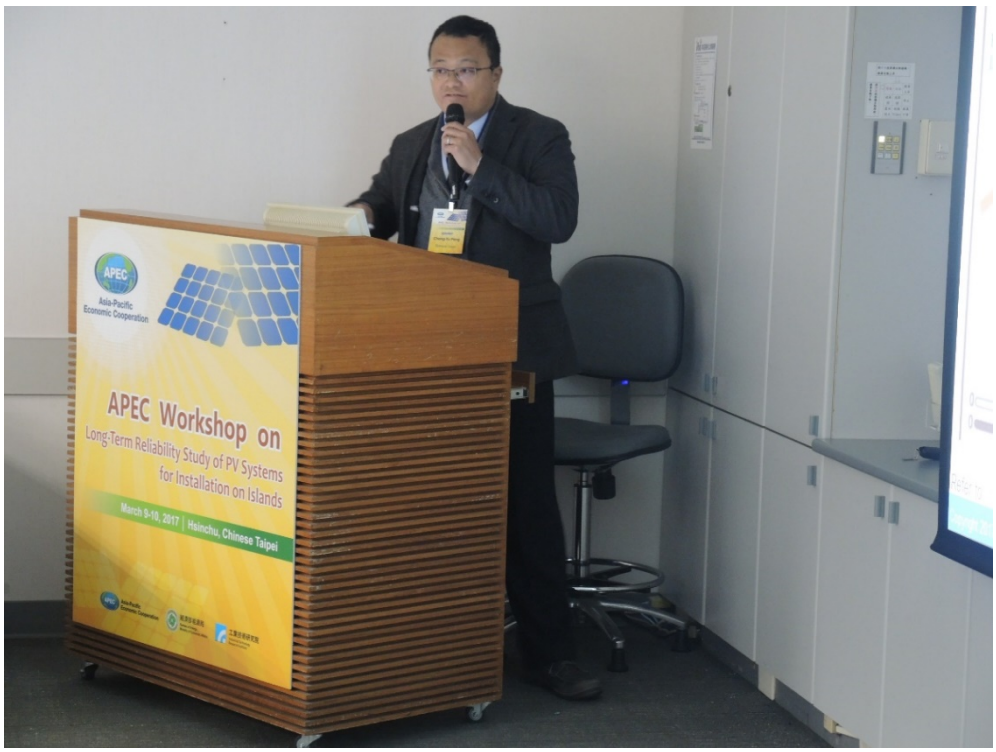


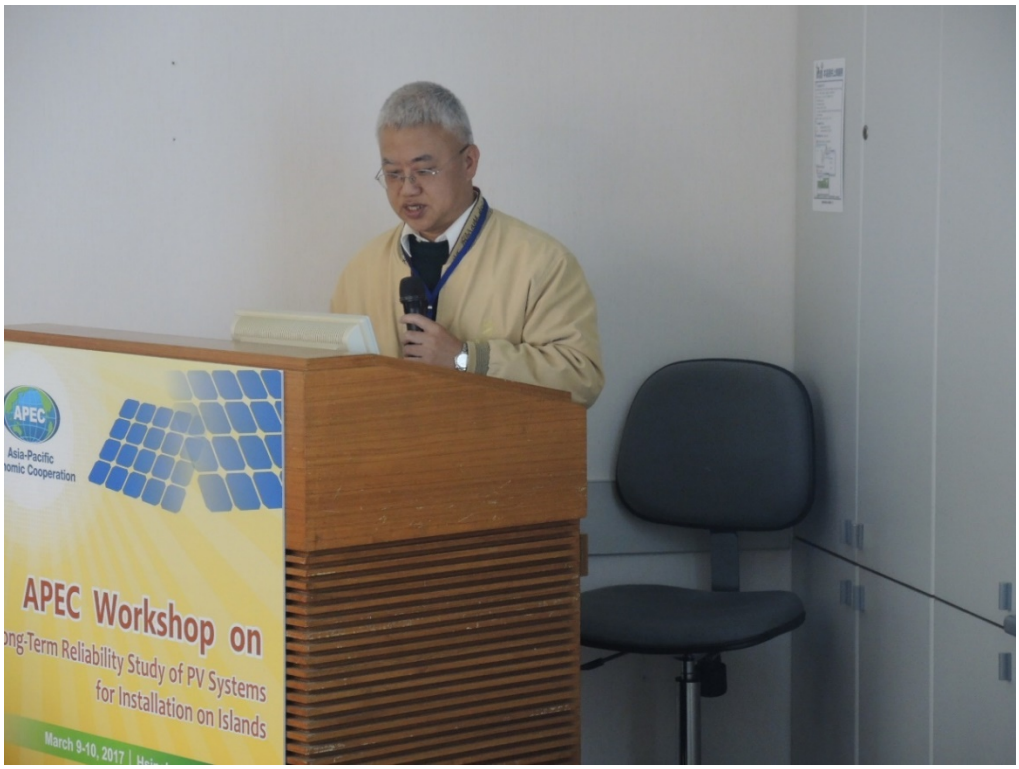
Speaker: Prof Hisakazu Okamura, Japan



Speaker: Ms Joanna Chen, Chinese Taipei



Speaker: Mr/Dr Cheng-Yu Peng, Chinese Taipei



Speaker: Prof Wen-Lung Lu, Chinese Taipei