



**Asia-Pacific
Economic Cooperation**

Small and Medium PV System Database in the APEC Region

Final Report

Expert Group on New and Renewable Energy Technologies

APEC Energy Working Group

November 2017

APEC Project: EWG 14 2015A

Produced by
Department of Alternative Energy
Development and Efficiency
Ministry of Energy, Thailand



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APEC#217-RE-01.24

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At present, the PV systems are becoming more economical with increased grid parity. APEC Energy Ministers also expressed their goal of doubling the share of renewables by 2030. The small and medium PV systems are the decentralized power sources which utilize the local resources in the environmentally friendly manor. The APEC members consist of developed and developing member economies. The grid connected PV systems could be found in both the developing and developed member economies. However, most of the off-grid PV systems could be found in the developing member economies. The developed and developing member economies could learn and facilitate each other to push forward the implementation of renewable energy technologies.

To obtain the maximum benefit of the PV systems in the future, PV system stakeholders should study from previous installed systems. Hence, there was a need for a systematic way and platform of recording and monitoring the operation of the PV systems. The platform could be web-based database for the Small and Medium PV System for information sharing on implementation and performance of the systems. Gathering and analyzing PV systems for best implementation practices was the key to increase the use of new and renewable energy. It was hoped that the open access database would benefit the stakeholders of the APEC member economies such as government, private, public, academic, and commercial sectors.

Objectives of the Project

This project seeks to create a collaboration to share information of small to medium scale PV system for the promotion of renewable energy.

1. To compile, collate, analyze, report, disseminate profiling of small to medium scale PV system information in selected grid connected and off-grid PV systems.
2. To initiate a strong institutional network for collecting, updating and maintaining the database for the PV systems in the APEC member economies.
3. To share the information of small to medium scale PV system status in a common platform as an information cloud sharing environment.

Methodology

1. Set up project organizing team of selected experts from 5 participating APEC economies.
2. Organize the 1st Project organization team meeting and the 1st workshop to determine the way forward, type of data, how to update and maintain the database and the structure of PV system database.
3. Design and create the web database “www.apecpv.cmru.ac.th” with the host at Chiang Mai Rajabhat University.
4. The member of the project organizing team input the data from small and medium scale PV systems to the database and fix the bugs from the program.
5. Organize the second project organization team meeting and the second workshop to share experience on data collection; input to the database; and determine the way forward for reporting format and data analysis concept to benefit all stakeholders.

Outcomes of the Project

Monitoring and recording all PV systems in all APEC member economies is a very challenging task. It required networks of institutions (public, private, and academic) in each economy for local data collection and updating the database. In this project, five economies participated: Indonesia; Malaysia; Thailand; United States and Viet Nam. There were two workshops held in Chiang Mai, Thailand on 26-27 September 2016 and Tokyo, Japan on 23 October 2017. The workshops were led by expert members with tailored program for experience sharing, brainstorming and collaboration. The workshop included several sessions with varying dynamics such as expert presentations, case studies discussion, and group breakout discussion. The focus of the workshop was the brainstorming regarding way forward for data sharing of the PV system under the database platform.

Workshop 1 provided guideline for Data Collection and Compilation; Processing, Analysis and Updating Database Methods; and Database Structure, Reporting, Maintenance and Sustainability. The data would be categorized into 3 Tiers: 1. General Information (no data logging), 2. Monthly Data (kWh, Solar Irradiation, etc.): averaged per month, 3. Detailed Performance: 1-10 min data logger. It was determined that the project consultant, Chiang

Mai Rajabhat University, was responsible to develop the database and coordinate between the participating economies.

In this project, data from 45 PV system sites from 5 economies were input into the database. The data were in the form of general data, average monthly performance data and very detailed performance daily data. Due to the variety of data format from each site, the participating economy and the database host trouble-shooted the issues from the website together. Due to proprietary information for many of the PV sites, the University network in this project provided the information for the 45 sites that could be shared.

The second workshop provided the venue for sharing of experiences and way forward in using the online platform. The recommendations from the experts and participants were: the need for data quality control; data collection based on IEC standard; standardize unit and time; easier way to input data; and file size limitation. The database should be more focused and more detailed such as on performance data, performance ratio, energy storage, power factor, kWh, location site mapping/geographical view, PV structure, CO₂ emission computations, energy consumption data and algorithm for forecasting. The project should develop data sharing agreement of how the data could be used and shared. There was also an opportunity for APEC database to be integrated with the IEA database. However, the database should be simple and not too complicated for data input. Low cost and wireless long-range data monitoring devices should be implemented for off grid systems. The collected data should be analyzed with big data analytics and machine learning to automatically report the useful information for the stake holders.

The way forward for the PV database should be to increase the awareness and the benefit of the database and use the existing network for data collection. The database should be built upon the network with EGNRET Network, IEA database, APERC, CSR, industry associations, and government monitoring.

Project Background

With the increase in the energy demand for economic development, the sustainable growth can be supported by the implementation of renewable energy such as PV systems. APEC Energy Ministers expressed their goal of doubling the share of renewables in the APEC energy mix by 2030. At present, the PV systems are becoming more economical with increased grid parity. The small and medium PV systems are the decentralized power sources which utilize the local resources in the environmentally friendly manner. PV systems required no fuel and had low-cost maintenance. Therefore, there were numerous of grid connected and off-grid PV systems deployment all over the APEC economies. However, the status of these systems were typically unknown. In order to develop grid connected and off-grid PV systems to obtain the maximum benefit in the future, PV system stakeholder should study from previous installed system. In addition, Thailand Ministry of Energy was very interested to establish a data sharing platform for renewable energy and community power technology within Thailand. The Department of Alternative Energy Development and Efficiency (DEDE) started a collection of data for off-grid PV, biomass and biogas systems. The data were displayed as the site location on Thailand Map. However, the Ministry still did not have a complete data for the off-grid PV systems.

Monitoring and recording all grid connected and off-grid PV systems in all APEC member economies is a very challenging and seemingly impossible task. It required networks of institutions (public, private, and academic) in each economy for local data collection and updating the database. In fact, some of the member economies already had their own database and this project could be linked to them as well. It was the ultimate goal of this project to initiate a strong institutional network to maintain this knowledge sharing database. This institutional network would be selected institutions with their own mission and on-going programs related to the research and implementation of renewable energy in their own member economies. These selected institutions should have strong networking with other institutions in their own economies as well. From this network, a main hosting institution would be selected to connect and help maintain the database platform.

The APEC members consisted of developed and developing member economies. The grid connected PV systems could be found in both the developing and developed member economies. However, most of the off-grid PV systems could be found in the developing

member economies. The developed and developing member economies could learn and facilitate each other to push forward the implementation of renewable energy technologies. To develop PV systems to obtain the maximum benefit in the future, PV system stakeholders should study from previous installed system. Hence, there is a need for a systematic way of recording and monitoring the operation of grid connected and off grid PV systems. One of the method was to create a common knowledge sharing platform for the PV systems in the APEC region. The platform could be in a form of a web-based database for the Small and Medium PV System for information sharing regarding the implementation and performance of the systems. Gathering and analyzing PV systems for best implementation practices is the key to increase the use of new and renewable energy. It was hoped that the database would benefit all the APEC member economies as open access online database that could be accessed by people in APEC member economies as well as people around the world. Moreover, the database would benefit various organizations such as government, private, public, academic, and commercial sectors.

The main goal of this project was to create a collaboration to share information of small to medium scale PV system for the promotion of renewable energy. The specific objectives were:

1. To compile, collate, analyze, report, disseminate profiling of small to medium scale PV system information in selected grid connected and off-grid PV systems.
2. To initiate a strong institutional network for collecting, updating and maintaining the database for the PV systems in the APEC member economies.
3. To share the information of small to medium scale PV system status in a common platform as an information cloud sharing environment.

The Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University was the consultant for this project. To achieve the main goal and specific objectives of this project, the methodology of the project was as follows:

Setting-up of project organization team

The consultant discussed with the project overseer, and set up the project team of 1 head and 5 selected experts from APEC member economies. Due to the budget and time limitations, the expert consultant focused on South East Asia part of the APEC member economies. The expert consultant also considered from the IEA Survey Report of PV Power Application and the IEA PVPS Task 2.

Ground-work, preparation & planning and implementation strategy formulated

The consultant organized one project organization team meeting and one workshop at Chiang Mai, Thailand. The total participants of 35 were invited to attend the workshop to discuss about PV system in their economy. The consultant also developed a project implementation plan and draft web portal with the structure of the database and data input process. The participants of the workshop were selected according to the experience regarding PV on-grid and off-grid system. They have the working knowledge and network connections to the PV sites in their respective economies.

Pilot work

The consultant set up a web portal with PV information from the pilot work for one pilot site. Chiang Mai Rajabhat University hosted the PV System Database and the database was maintained through the university server for the entire project period. The hosting could be extended after project completion through the university Smart Grid Network projects. In addition, the project team would work with the project overseer to determine the most efficient and optimum web portal host as well.

Full implementation

The consultant organized project organization team meetings and workshop 2 in order to share knowledge about PV system and determine guideline and responsibility party to maintain the online database website. Way forward and protocol to update the information in the web portal were established.

Completion and submission of final report

The consultant updated online database and submitted the final report. Monitoring of the online database would still be assisted by Chiang Mai Rajabhat University and the project organizing team after the ending of the project with the provision from the project overseer.

Project Team Members

The project team leader and project head for each economy were identified from workshop 1 and project meetings. The project leaders of the project organization team are listed below.

| | Name | Position/Organization | Economy | Email |
|---|---------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------|
| 1 | Dr Worajit Setthapun | Project Leader Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University | Thailand | worajit@ cmru.ac.th |
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| 4 | Dr Sulak Sumitsawan | Project Head - Thailand School of Energy and Environment University of Phayao | Thailand | sulak.sumit@gmail. com |
| 5 | Dr Leon Roose | Project Head – United States Hawaii Natural Energy Institute, University of Hawaii | United States | lroose@hawaii.edu |
| 6 | Assoc Prof Dr Dung Phan Quoc | Project Head - Viet Nam Ho Chi Minh City University of Technology | Viet Nam | pqdung@ hcmut.edu.vn |

Team Meeting 1

The meeting of the project organization team was held prior to the starting of the 1st APEC Workshop on Small and Medium PV System Database in the APEC Region. The main objective of the team meeting 1 was to brief the final detail of the workshop agenda, discuss the role and responsibilities of the team members, discuss the objective and expected outcome of each workshop activities, and determine the detailed and key discussion points during the workshop group breakout session.

Agenda Briefing and Expected Outcome of Each Activities

Dr Worajit Setthapun briefed the team on the project goals and the final details of the workshop agenda. The main goal of the workshop was to create a strong network among the participants by creating an environment where all the participants could get to know each other as much as possible, share their experience, expertise and ideas of how to work together to create a PV system database. Gathering the information from the APEC member economies is a very challenging task. This project aimed for the bottom-up approach where the network of members and institutions from the volunteer economies could gather and share the PV data in the common platform. The small platform if proven useful could grow to be a larger database platform. Dr Sulaiman Bin Shaari explained that the workshop participants could assist in the compile of the data and provide ideas on the component and structure of the database platform. The participants input on the type of data, reporting and sharing method were very important in the database development. Then, the Chiang Mai Rajabhat University (CMRU) team would assist with developing the database on the university's network in a cloud sharing environment.

For the details of the workshop, the Asian Development College for Community Economy and Technology (adiCET) staff would be responsible for all the logistics, paper work, summary, and media. The agenda would be grouped into 5 parts: Opening ceremony, Keynote and Invited speakers, Project discussion, Group breakout, and Conclusion/Way-forward.

The opening ceremony would be provided by Mrs Kulwree Buranasajjawaraporn, the Director of Solar Energy Development Bureau, Department of Alternative Energy

Development and Efficiency (DEDE), Ministry of Energy, Thailand. Assistant Prof Sukanya Kamnuansakunee, the Vice President of CMRU would be providing the welcome address. Dr Setthapun would be taking care of Mrs Buranasajjawaraporn and brief her about the goal of the project. Dr Setthapun would be providing the Chiang Mai World Green City tour to Mrs Buranasajjawaraporn with the focus on the Small and Medium Scale PV Systems.

The next part was the keynote and sharing of best practices. Dr Tetsuyuki Ishii would be providing the overview of the PV system database as the global perspective. Dr Ahmad Maliki Omar and Mr Paul Rodden would be sharing their best practice experience from the perspective of Malaysia and Australia. The main goal of the presentations was to provide the workshop participants with the background of the PV system database and how to collect the data and update the database.

Dr Setthapun and Dr Bin Shaari would brief the workshop participants about the aim, objectives, expected outcomes, proposed methods, implementation, timeframe and constraints to all participants. The explanation would focus on the importance of the workshop member participation to the success of the project.

The breakout group was the most important part of the workshop. The leaders and facilitators of each group were brief on their role and responsibilities. They must try to create the discussion environment where the group members could provide their thoughts and ideas on how to develop the database. In addition, the leaders and facilitator must draw-out the need, requirements, and expectations of the member economies. The reporting part of the database should provide benefit to the member economies to assist in the understanding and promotion of Renewable Energy in the APEC region. During the discussion, the secretary of the group was assigned to help taking notes and summarizing key talking points.

The last part on the second day would be the conclusion and ways-forward. The expectation for this part was to receive the commitment of the participating members to help collect and update the PV data to the PV database. The timeline and responsibilities would be planned and delegated.

Role and Responsibilities of Team Member

The role and responsibilities of the team members were discussed. Dr Worajit Setthapun would be responsible for the overall running of the workshop. Dr Sulaiman Bin Shaari would be responsible for the technical aspect of the workshop. Dr Ahmad Maliki Omar,

Dr Tetsuyuki Ishii, and Mr Paul Rodden would be the resource persons for the workshop. Dr Hathaithip Ninsonti would be the secretary of the workshop and compile all information. Mr Panupong Intawong would be responsible for the logistics of the workshop.

Arrangement and Overall Goal for Workshop Group Breakout

The group breakout session was the most important part of the workshop. Based on the agenda, there would be 3 breakout groups. Each group would have the leader to guide the discussion and keep the discussion on the talking points. The leader would help to summarize the idea from the group to achieve the goal of the breakout session. Each group would also have a resource person as the facilitator to provide information and help provide ideas during the discussion. The topic of each group would be different. Group 1 would focus on data collection and compilation method. Group 2 would focus on method for processing, analysis and updating database. Lastly, Group 3 would focus on the database structure and ways to report and maintain the database sustainably. The team members then provided ideas and details of the specific key question and discussion points. The talking points would focus on the detail of method, expectations, responsible entity and way forward for each topic.

Team Meeting 2

EWG 14 2015A project meeting 2 was held in series after Workshop 1 in Chiang Mai. The project meetings were from several site visits and web meetings to evaluate the database after it was been tested with the Thailand's PV system data. The technical issues were addressed which include registration issues; alternative ways to upload the data; reevaluate the data field for relevancy; simplify the procedure; correct the units; include the logo of the institutional network; and increase the size of upload file limitations. Project leader fixed and trouble-shoot the online database according to the recommendations from the participant of each economies. University of Hawaii from Hawaii Natural Resource Institute (HNEI) expressed interested to contribute their PV system data into the database. HNEI had extensive experience on Small/Medium/Large Scale PV system installation and monitoring. HNEI also had their own monitoring devices, PV database and analytical tools. The

participation from United States as the developed economy was beneficial to help improve the database for the developing economies as well.

For the organization of the second workshop, the date and venue were rescheduled from Shah Alam, Malaysia to Tokyo because EGNRET requested for the workshop to be held alongside the EGNRET 49 meeting in October 2017. The Thailand PO agreed with the consent of the project team members. APEC Secretariat informed that the budget could not support the participating economies as proposed in the proposal. However, holding the second workshop in Tokyo would benefit from the attendance from the EGNRET economy representatives. In addition, the venue was in IEEJ building and the APERC team could also attend. However, due to the limited conference room availability, the second workshop was condensed into one day instead of the originally planned of two days. Therefore, the second workshop was decided to be moved to 23 October 2017 in Tokyo, Japan.

Summary of Workshop 1

The 1st APEC Workshop for the Small and Medium PV System Database in the APEC Region was held on 26-27 September 2016 at Chiang Mai, Thailand. The venue was at Chiang Mai World Green City, Chiang Mai Rajabhat University, Maerim Campus. This workshop was the kick-off activity for the EWG 14 2015A project. The main motivations of the project were that there were vast numbers of grid-connected and off-grid PV systems all around the APEC economies. Over the years, these systems aged and would need to be reworked on. In order to achieve maximum outputs as per designed, these systems must be monitored appropriately. However, quite often, it was found that there were incomplete data and information of these systems, then and now. Therefore, a database of knowledge-sharing platform would be very useful to the stakeholder for benchmarking and planning activities. Hence, there was a need for a systematic way of recording and monitoring the operation of these systems. The workshop would help provide a venue for brainstorming session to deliver the systematic way of monitoring the PV systems which could be benefit to all economies. It was the ultimate goal of this project to initiate a strong institutional network to maintain this knowledge-sharing database. This institutional network would be selected institutions with their own mission and on-going programs related to the research and implementation of renewable energy in their own economies.

Objectives of Workshop 1

- To determine ways to compile, collate, analyse, report, disseminate profiling of small to medium scale PV system information in selected GC and OG PV systems.
- To initiate a strong institutional network for collecting, updating and maintaining the database for the PV systems in the APEC member economies.
- To develop structure for the sharing platform small to medium scale PV system status.

Workshop 1 Agenda

**APEC Workshop on Small and Medium PV System Database in the APEC Region
26-27 September 2016
Chiang Mai, Thailand**

| Monday 26 September 2016 | |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08.30 | Registration |
| | Opening Session |
| 09.00 | Introductory remarks <i>Dr Worajit Setthapun</i> Dean, Asian Development College for Community Economy and Technology, Chiang Mai Rajabhat University, Thailand |
| 09.10 | Welcoming address <i>Mrs Kulwree Buranasajjawaraporn</i> Director of Solar Energy Development Bureau Department of Alternative Energy Development and Efficiency Ministry of Energy, Thailand |
| 09.20 | <i>Assistant Professor Sukanya Kamnuansakunee</i> Vice President Chiang Mai Rajabhat University, Thailand |
| 09.30 | Group Photo Session |
| 10.00 | Keynote Address – World Overview on PV Systems Database PV Systems Database at the Global Perspective <i>Dr Tetsuyuki Ishii</i> Central Research Institute of Electric Power Industry (CREPI), Japan |
| 10.45 | Coffee Break |
| 11.00 | Best Practice for Small and Medium PV System Database in the APEC region Master of Ceremony (MC) introduces and invites speakers to share their views, experiences and suggestions on how to collect, process and analyze data, manage and sustain the database. |
| 11.10 | Collecting, analysing, reporting and managing PV systems databases <i>Dr Ahmad Maliki Omar</i> Universiti Teknologi MARA, Shah Alam, Malaysia |

| Monday 26 September 2016 | |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11.40 | <p>PV Systems database in the Australian urban and outback communities <i>Mr Paul Rodden</i> CAT Projects, Alice Springs, Australia</p> |
| 12.10 | Lunch |
| 13.30 | <p>Briefing: The APEC project and Proposed Database Template This session introduces the complete project details, e.g. aim, objectives, expected outcomes, proposed methods, implementation, timeframe and constraints to all participants. A proposed working database template for possible use in this project will be discussed.</p> <p>The APEC project – Part 1 Introduction to the APEC-funded project: types of data; data collection; structure of database. <i>Dr Sulaiman Shaari</i> Universiti Teknologi MARA, Malaysia</p> |
| 13.40 | <p>The APEC project – Part 2 Introduction to the APEC-funded project: Methodology of updating; timeframe; constraints; expected outcomes and benefits; maintenance and sustainability. <i>Dr Worajit Setthapun</i> adiCET, CMRU, Thailand</p> |
| 13.50 | <p>The Proposed Database Template Description of a possible working template for a prospective PV systems database to meet the project aim and objectives. <i>Dr Tetsuyuki Ishii</i></p> |
| 14.10 | <p>Group Break-out – Part 1 General Chair and Main Facilitator: <i>Dr Tetsuyuki Ishii</i> The aim of this parallel session is to obtain a workable detailed workplan, set of activities, facilities required and the personnel identified to successfully complete the project. It includes the setting-up of economy level working group committees, identify their responsibilities and project timeline activities.</p> <p>Participants break-out into 3 groups to discuss in detail the topics listed.</p> <ul style="list-style-type: none"> - Group 1: Data Collection and Compilation Methods Leader: <i>Dr Sulaiman Shaari</i> Facilitator: <i>Mr Paul Rodden</i> |

| Monday 26 September 2016 | |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | <ul style="list-style-type: none"> - Group 2: Processing, Analysis and Updating Database Methods Leader: <i>Dr Eko Setiawan</i> Facilitator: <i>Dr Tetsuyuki Ishii</i> - Group 3: Database Structure, Reporting, Maintenance and Sustainability Leader: <i>Dr Worajit Setthapun</i> Facilitator: <i>Dr Ahmad Maliki Omar</i> |
| 16.30 | Wrap-up of Day 1 <i>Dr Worajit Setthapun</i> |
| 16.45 | Coffee Break |
| 18.00 | Welcoming Dinner |

| Tuesday 27 September 2016 | |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 09.00 | Recap from Day 1 and Briefing of Activities for Day 2 <i>Dr Sulaiman Shaari</i> |
| 09.15 | Group Breakout – Part 2 Continuation of Part 1 in parallel session and finalization by each Group |
| 11.15 | <p>Plenary Session General Chair and Main Facilitator: <i>Dr Ahmad Maliki Omar</i></p> <p>Way forward for Small and Medium PV System Database in the APEC Region</p> <ul style="list-style-type: none"> - Based on the group discussion and breakout sessions, each Group’s representative shall present the Group’s ideas and conclusion. - In addition, the way forward for the operation of the project will be elaborated. - Questions and Answers |
| 12.15 | Lunch |
| 13.30 | <p>Correction, Recuperation and Consolidation Session General Chair and Main Facilitator: <i>Mr Paul Rodden</i></p> <p>Group leaders edit their presentations and contents to take into consideration the comments from the preceding session. Before the end of session, group leaders convene with <i>Dr Tetsuyuki Ishii</i> and the facilitators to arrive at a consolidated final document.</p> |
| 14.30 | <p>Deliberation of Consolidated Document and Wrapping-up of Workshop <i>Dr Tetsuyuki Ishii</i> deliberates the overall consolidated document. <i>Dr Worajit Setthapun</i> wraps up the Workshop and gives an Adjournment remark.</p> |

| Tuesday 27 September 2016 | |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15.00 | Coffee Break |
| 15.30 | Tour of Chiang Mai World Green City – GC and OG PV Systems Case Studies <ul style="list-style-type: none"> - Model Community with DC Power Systems and Microgrid (Off-Grid) - 700 kW GC system - PV Rooftop GC system - PV Ground-mounted community AC microgrid |
| 17.00 | Adjourn and Departure |

| Attachment: Details for Group Breakout Session | |
|------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14.10 | <p>Group Breakout – Part 1 General Chair and Main Facilitator: <i>Dr Tetsuyuki Ishii</i></p> <p>The aim of this parallel session is to obtain a workable detailed work plan, set of activities, facilities required and the personnel identified to successfully complete the project. It includes the setting-up of economy level working group committees, identify their responsibilities and project timeline activities.</p> <p>Participants breakout into 3 groups to discuss in detail the topics listed.</p> <ul style="list-style-type: none"> - Group 1: Data Collection and Compilation Methods Leader: <i>Dr Sulaiman Shaari</i> Facilitator: <i>Mr Paul Rodden</i> - Group 2: Processing, Analysis and Updating Database Methods Leader: <i>Dr Eko Setiawan</i> Facilitator: <i>Dr Tetsuyuki Ishii</i> - Group 3: Database Structure, Reporting, Maintenance and Sustainability Leader: <i>Dr Worajit Setthapun</i> Facilitator: <i>Dr Ahmad Maliki Omar</i> |

Suggested Key Questions for Group Breakout Session

Group 1: Data Collection and Compilation Methods

- What type of data is necessary for the PV off-grid and on-grid system database?
- What data can be shared and what data is sensitive to share?
- What is the best method to collect the PV off-grid and on-grid system?
- Who should be in the working group for data collection?
- How should we get them involve with the project?
- What kind of mechanism/ process/ activities are appropriate for data collection?
- What tasks/activities should be in the work-plan for setting up data collection and compilation for PV database?

- What should be the timeframe for data collection?
- What are the expected challenges and obstacles?

Group 2: Processing, Analysis and Updating Database Methods

- How should the data be processed and analyzed to yield the most benefit the database user?
- How should the database be updated and what is the frequency?
- Who should be responsible for updating the database?
- What kind of institutional network can facilitate the database updating?
- What kind of mechanism/ process/ activities are appropriate for data updating?
- What tasks/activities should be in the work-plan for processing, analysis and updating PV database?
- What are the expected challenges and obstacles?

Group 3: Database Structure, Reporting, Maintenance and Sustainability

- How should the database be structured?
- How should the data be reported?
- How should the database be maintained?
- What tasks/activities should be in the work-plan for reporting and maintaining the PV database?
- Who or what organization should be responsible for maintaining the database?
- What are the expected challenges and obstacles?

Workshop 1 Participants

There were 37 participants attending the workshop from 8 economies. The female gender ratio was 32.4% with 12 female participants and 25 male participants.

| | Name | Position/Organization | Email | Gender | Economy |
|---|---------------------------|--------------------------------------------------------------------------------------------|--------------------------------|---------------|----------------|
| 1 | Mr Paul RODDEN | Senior Project Manager – Renewables CAT Projects | Paul.Rodden@catprojects.com.au | M | Australia |
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| 4 | Dr Tetsuyuki ISHI | Central Research Institute of Electric Power Industry(CREPI) | tetsu@criepi.denken.or.jp | M | Japan |

| | Name | Position/Organization | Email | Gender | Economy |
|----|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|--------|------------------------------------------|
| 5 | Mr GHO Wei Chiun | Senior Engineer Sarawak Energy Berhad (SEB), Kuching, Sarawak | GohWeiChiun @sarawakenergy. com.my | M | Malaysia |
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Workshop 1 Content and Outcomes

Presentations

During the first day of the workshop (September 26, 2017), the opening address was delivered by Mrs Kulwree Buranasajjawaraporn, Director of Solar Energy Development Bureau, Department of Alternative Energy Development and Efficiency, Ministry of Energy, Thailand. In her speech, she focused on the need for using the collective experiences to create the collaborative information sharing platform for the on-grid and off-grid PVs in the APEC region. The alignment in design, installation, operation and maintenance had not been established for the region. Sharing information on best practices of on-grid and off-grid PV systems was therefore very challenging, but it was also extremely useful to help assist the existing systems and the move of PV penetration in the same direction.

The Keynote address “World Overview on PV Systems Database PV Systems Database at the Global Perspective” was delivered by Dr Tetsuyuki Ishii, Central Research Institute of Electric Power Industry (CREPI), Japan. IEA reported that the global solar cumulative PV installations reached at least 227 GW by the end of 2015. Investors, customers, and even suppliers focused on the “bankability” of PV technologies. The reliability and durability of PV modules largely influenced by solar PV power generation cost. Therefore, monitoring and operating the system at the optimal performance would provide the most efficient return. He also shared the experience from Japan on the data structure of data collection. Only the electric power companies had PV System Database where the energy use was monitored by smart meters every 30 minutes.

The invited presentation was from Dr Ahmad Maliki Omar, Universiti Teknologi MARA, Shah Alam, Malaysia. He shared his experience regarding collecting, analyzing, reporting and managing PV systems databases. Typically, different parties had different interest on database. Therefore, the database should clearly define the purpose. There were generally three types of database: System information, Standard data and Detailed data. The level of complexity of database depends on user requirements. Detailed data base was costly but it gives detail knowledge on the system condition. The gathering data required commitment all parties and the systematic arrangement of data in database could speed up data analysis. However, there were many challenges to develop the database such as: Cooperation with the plant owner; Some large scale solar farms did not have telecommunication network; Mostly

standalone PV systems were located at remote location; Funding; Government; Plant owner; Good quality data from WMS sensors; Most system had their own protocol to send data to their own server; Impossible to receive continuous online raw data; Problems with internal communication networks of the plant; Good quality of data from data logger; Missing data and Data not in proper sequence. Even with many challenges, the database was very important. Learning from historical data would help for future planning.

Another resource person was Mr Paul Rodden from CAT Projects, Alice Springs, Australia. He shared his experience on the PV Systems database in the Australian urban and outback communities. He provided examples of how to collect the data with PV: Industrial grade AC meters (+/- 0.5% accuracy). The data must be conditioned before being stored on server (Schneider ION) and UPS back up power for short term outages. For the management of data, the host server should be physically located on DKA campus (ie. 800 m away). The communication was by fiber optics. The database was developed using Microsoft SQL server 2012 and SQL agent for data quality checks. The size of data had to be considered, Non archived (trade off size and speed) and Image back-up twice per week on FIFO basis. Regarding to sharing of data, there were DKASC website portal for data sharing where all data files could be downloaded as .csv. The website host was on separate server. In conclusion, in order to develop a usable database, consideration must be made regarding:

- Why collect the PV data?
- What PV Data needs to be collected?
- How will the data be collected, managed and shared?

Breakout Session

The workshop focused on the 3 breakout groups discussion from the participants. Each group had the Leader, Facilitator and Secretary. The expected outcomes of the group discussions were that Group 1 was to provide ways forward for data collection and compilation methods; Group 2 was to provide methods for processing, analysis and updating database; Group 3 was to provide guideline for database structure, reporting, maintenance and sustainability.

Group 1: Data Collection and Compilation Methods

Leader: Dr Sulaiman Shaari

Facilitator: Mr Paul Rodden

Members:

Mr Wei Chiun Goh

Mr Hung Le Van

Ms Marlina Pandin

Ms Maricel C. Dela Cruz

Mr Duc Vu Ngoc

Dr Nuttiya Tantranont (Secretary)

Group 1 suggested that the working group involved in developing the database should be the Government authority, ministry, utility as the main role and university. The group discussed the purpose/reason for database, the database, implementation scheme and way forward.

Purpose and Reasons

- Purpose of Database
 - To provide enough & accurate data on PV system to satisfy the needs of all stakeholders
- Why would people want to use the database?
 - Return of Investment – *Financier, Government policy makers, Utility*
 - Performance / Reliability; CAPEX/OPEX; Quality /Standard; Implementation
 - Due diligence – *Government policy makers, Educators, Utility*
 - Awareness – *Financier, Government, General public, Utility*
 - Network planning – *Utility, Government policy makers, R&D*
 - Controls, operation, maintenance – *Utility, R&D*
 - Optimum design – *Financier, R&D, Government, Educators, Utility*
 - Environment – *Government, R&D, Financier, General public /Consumers*
 - Capacity building – *Educators*
 - Support and develop government policy

Database Stakeholder

Basic

- Government policy makers
- General public / Consumers

Detailed

- Utility; Educators; R&D; Financier; Manufacturers/ Industry

Types of data

- General information
 - System data; Ambient; Dates of commissioning & decommissioning
- Economic data
 - Least cost of energy (LCOE)
 - Incentives / Drivers
- Installed / Operating capacity
- Performance data: Tier 1, 2, and 3
- Resource data: Global Horizontal Irradiation (GHI)
- Geographical data
- Production / Yield data over lifetime
- Storage; SOC, DOD, Cycles, User Consumption, Losses
- Auxiliary power

Database Structure

| Data Category | Parameter | Tier 1 | Tier 2 | Tier 3 |
|---------------|-------------------------|--------|--------|--------|
| General | Date of commissioning | | | |
| | Date of decommissioning | | | |
| | ON Grid - OFF Grid | | | |
| | etc | | | |
| | etc | | | |
| Resource | GHI | | | |
| | GI - POA | | | |
| | Ambient Temp | | | |
| | Module temp | | | |
| | Rainfall | | | |
| | Wind | | | |
| | | | | |
| Geographical | GPS coordinate | | | |

| Data Category | Parameter | Tier 1 | Tier 2 | Tier 3 |
|---------------|-------------------------|--------|--------|--------|
| | Region/State | | | |
| | Territory | | | |
| | | | | |
| System | kWp - installed | | | |
| | Inverter type | | | |
| | Module type | | | |
| | Battery | | | |
| | Charge Controller | | | |
| | Generator | | | |
| | | | | |
| Performance | kWh | | | |
| | kW | | | |
| | PR | | | |
| | V | | | |
| | Hz | | | |
| | Etc, freedom for tier 3 | | | |
| Financial | Capex \$ | | | |
| | Opex \$ | | | |
| | Incentive - FiT | | | |
| | Incentive - adder | | | |
| | Incentive - capex | | | |

Incentives / Drivers & Constraints

- **Incentives / Drivers**

- FIT, Net Energy Metering, Adder, Capex subsidy, Tax break, Consumption tariff

- **Constraints:**

- Network/grid, Land, Financial, Regulatory, Social constraint, Political constraint

Way forward

- **What kind of mechanism / process / activities are appropriate for data collection?**

- Demonstrating Benefit (Education PV user)
- Packaged in contract / tender
- Terms of reference
- Pre-approved components list
- Government/ Utility request

- **What are the expected challenges and obstacles? (combine later)**
 - Information dissemination
 - Consistency of data
 - Compatibility – sensors
 - Quality / precision / accuracy
 - Stakeholder engagement / involvement / resistance
 - Too many agencies/players – linking, complexity, red tapes
 - Lack of institutional mechanism
 - Leadership without vision

What data can be shared and what data is sensitive to share?

- Economic data
 - Generic data - macro data (share)
 - Linked to project/ site specific (sensitive)
- Operating data – especially things that are not working well
- Detailed Resource data (high resolution data)

What tasks/activities should be in the work plan for setting up data collection and compilation for PV database?

- Finalizing the data parameters
- Finalizing data format
- Identifying data sources / persons who in charge
- Choosing pilot site
- Sourcing data
 - Undertaking by each member economies
- 12 months project
 - Pilot - 3 months
 - Full implementation - 9 months

Group 2: Processing, Analysis and Updating Database Methods

Leader: Dr Eko Setiawan

Facilitator: Dr Tetsuyuki Ishii

Member: Assoc Dr Wattanapong Rakwichian

Mr Pichet Nuanual

Mr Anuchat Wangtaweewong

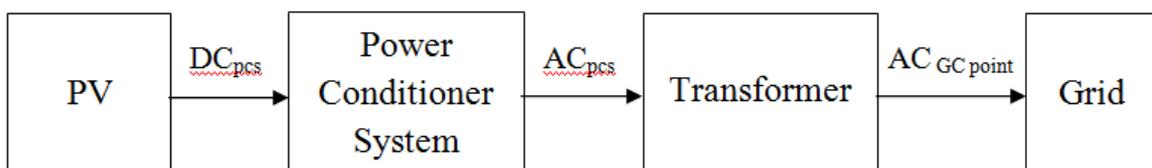
Dr Hathaithip Ninsonti (Secretary)

1. How should the data be processed and analyzed to yield the most benefit the database user?

First of all, which parameters to be collected should be considered. Then, data collection pattern should be designed. The type of data set should be simple (general data) and detailed data. Simple data (important) 1st level should be just the information about the system such as capacity, yield, location, configuration, basic fundamental specification and do not need data logger. The detail data (optional) 2nd level should have monitoring devices for monthly activity such as:

Electrical data

- DC_{pcs} (Voltage, Current)
- AC_{pcs} (Power factor, Voltage, Current)
- $AC_{GC\ point}$ (Energy in kWh)



Ambient condition data (Tier 3)

- In-plane solar irradiance
- Back side module temperature
- Direct irradiance *
- Diffuse irradiance *
- Spectral irradiance * (tier 4)
- Ambient temperature *

- Wind velocity *
- Wind direction *

* Although these data were usually measured, they were not essential for flat plate PV module research.

Performance ratio (PR) calculation

$$PR = \frac{\text{Production energy}}{\text{Expected energy}} = \frac{\text{Production energy}}{\sum_t \left[\text{Irradiance} \left[\frac{W}{m^2} \right] \times \frac{\text{Peak power} [W]}{1000 W/m^2} \right] \times \left[1 + (\text{Temp} [^{\circ}C] - 25^{\circ}C) \times \text{Temp Coefficient} \left[\frac{\%}{^{\circ}C} \right] \right]}$$

- Temp is the module temperature sensor measurement, in °C
- Temp Coefficient is the module’s Pmpp temperature coefficient, taken from the module datasheet, and is always a negative value in %P/°C (or %P/°K)

2. How should the database be updated and what is the frequency?

| Data set | Data record | Data update |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Simple data Tier 1 | Manually recorded by system owner | Manually updated database every year <u>Responsibility</u> Project team (working group)/ Government |
| Tier 2 | Once a month kWh weather | |
| Detail data Tier 3 | Automatically recorded using data logger every 1-5min (5 min – Malaysia & Australia from IEA, Default value of inverter) (1-10 min – Japan) | Automatically updated database trough internet every night (because PV system stop operating) <u>Responsibility</u> System owner <ul style="list-style-type: none"> - Electric aggregators - Utility companies - Independent Power Producer (IPP) |

3. What kind of institutional network can facilitate the database updating?

- APEC network
- Academic network
- Institution to Make Database
- Institutions to provide data

4. Suggestion (Reporting/end use)

- This project should suggest how to make best practice for PV monitoring by learning from Japan and Australia.
- This project should suggest how to analyze short and long-term performance of PV system.
- This project should suggest how to analyze failure and malfunction of PV operation.
- This project should suggest how to analyze batteries quality or reliability for off-grid system and which parameter those affect to battery i.e. ambient temperature, voltage level.
- For batteries temperature analyzer, thermal imaging using IR camera could be used.

5. Challenges (Compile with others)

- Good infrastructure - required for the communication especially for OG system that installed in the remote area such as island.
- Large size of data storage - required.
- Output data collected from different instrument (data logger, inverter) model would be difficult to be combined together.
- Long term funding was the most important thing to continue PV performance monitoring in both GC and OG PV system.

Group 3: Database structure, reporting, maintenance and sustainability

Facilitator: Assoc Prof Dr Ahmad Maliki Bin Omar – Malaysia

Leader: Dr Worajit Setthapun – Thailand

Member:

Assoc Dr Phan Quoc Dung – Viet Nam

Mr Ishamuddin Bin Mazlan – Malaysia

Mr Kang Yang Chia – Singapore

Ms Jingyi Zhuo – Singapore

Database Structure

The database structure should be categorized into 2 phases of development.

- Phase 1:
 - Each economy should send example data for 2 on-grid/ 2 off grid sites/economy
 - The update should be 1 time/month and use the standardize format
 - Grid Connected
 - Small 1 - 72 kW (Malaysia)
 - Medium >72 kW > 1 MW
 - Off Grid
 - Small 1-10 kW
 - Medium 10 kW → 1 MW
 - Data collection start from public funding project
 - Develop common platform as grid connected and off-grid
 - Link to attribution: Capacity, kW peak, technology, location
 - Trouble shoot
- Phase 2:
 - Each economy set up their own database/or existing one
 - Set up transformation tool
 - Link own database to common platform
 - Link in **Push data format** and Filter data before sending
 - Set up term of use for ownership; Ownership; Different kind of data (share/not share); Basic or Detailed and Security
 - Determine size for data pool for common platform
 - Set up useful analytics for data matching

Reporting (based on tiers)

- Compare Technology: Technical specification & Investment – public/private funding
- Compare Performance ratio: Solar irradiation level & Specific Yield
- Compare Reliability: work/not work
- Compare Sustainability of system
- Need to determine protocol for access and interface

Updating

- Data can be push from own economy database
- For Example: SEDA – have mandate for data collection/ must have own server and Thailand – Energy Regulatory Commission
- Updating from energy volunteers and provincial energy officer (Thailand)

Sustainability-Suggestion

- Ownership of database should belong to government
 - Malaysia – SEDA/Thailand – DEDE
- Funding for database:
 - Government: Malaysia example Trust fund 1% from total revenue of electric sales/ Thailand – Energy Conservation fund
 - International organization: World Bank, APEC, etc.
 - Sponsorship from PV manufacturers
- Involve the private industry

Challenges

- Not just have a report; Sustain database (Policy, People, Funding)
- Common format/Sharing

Summary for Way forward with the EWG 14 2015A APEC Project

The database should be structured as 3 tier data system with Tier 1 (General Data), Tier 2 (Averaged Monthly Data), and Tier 3 (Detailed data with data logger). Due to the challenges and confidentiality of data sharing and reporting, the APEC project should start with data from 2 on-grid sites and 2 off grid sites per economy. Project team from five economies should participate to submit the data to the online sharing platform such as Thailand, Malaysia, Viet Nam, Indonesia and the Philippines. Chiang Mai Rajabhat University should design and established an easy to use interface – online sharing platform under the university's server. The method to upload the data should be simple with flexible way for data sharing. The project team from each economy was responsible for selecting and uploading the database. Any issues during data collection and uploading should be communicate to the project leader. During the second workshop, experience of using the database could be shared to determine way to improve the database to be useful for all APEC economies.

Workshop 1 Pictures

Opening Session



Keynote Address



Group Breakout



Welcoming Dinner



Plenary Session and Conclusion



Site Visit of Chiang Mai World Green City



Summary of Workshop 2

The workshop was led by expert consultants with a tailored program for experience sharing, brainstorming and collaboration. The workshop included several sessions with varying dynamics such as expert presentations, case studies discussion, and group breakout discussion. The focus of the workshop was the brainstorming session regarding way forward for data sharing of the PV system under the database platform: <http://apecpv.cmru.ac.th>. This workshop was a continuation of previous APEC workshops held in Chiang Mai Thailand (September 2016).

Objectives of Workshop 2

- to discuss about the methods of data collection of the PV systems and determine the optimal way forward for the sustainability of data collection
- to continue and enhance the institutional network for maintaining the database platform for the benefit of all stakeholders
- and lastly to share the information and best practice of the selected on-grid and off-grid PV systems in a common platform as an information cloud sharing environment

Workshop 2 Agenda

The 2nd APEC Workshop on Small and Medium PV System Database in the APEC Region

23 October 2017

The Institute of Energy Economics, Tokyo, Japan

| Agenda | |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 08.30 | Registration |
| 09.00 | Workshop/Project Overview Dr Worajit Setthapun Project Leader Chiang Mai Rajabhat University, Thailand |
| 9.10 | Opening Session Welcoming Speech Dr Tom H.T. Lee APEC Expert Group on New and Renewable Energy Technologies |
| 9.20 | Opening Speech Mrs Munlika Sompranon Director of Energy Cooperation Section Department of Alternative Energy Development and Efficiency Ministry of Energy, Thailand |

| Agenda | |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 09.30 | <p>Keynote – IEA PVPS Task 13 Overview on the Implementation of PV System Database Dr David Parlevliet School of Engineering & Information Technology Merdoch University, Perth, Australia</p> |
| 10.00 | Coffee Break |
| 10.20 | <p>Invited Presentation: Small and Medium Scale PV System Data Collection and Analysis Dr Nor Zaini Ikrom Zakaria Faculty of Applied Sciences Universiti Teknologi MARA, Malaysia</p> |
| 10.40 | <p>Database, Data Analytics, and Data Utilization for PV Systems Associate Prof Dr Chun-Liang Tung Department of Information Management National Chin-Yi University of Technology, Chinese Taipei</p> |
| 11.00 11.15 11.30 11.45 12.00 | <p>Project Update and Sharing of Experiences for Small and Medium PV System Data Collection and Database: Dr Eko Adhi Setiawan, Indonesia Dr Ahmad Maliki bin Omar, Malaysia Dr Sulak Sumitsawan, Thailand Dr Dung Phan Quoc, Viet Nam Ms Staci Sadoyama, United States</p> <ul style="list-style-type: none"> • Speakers would share the progress of the project and demonstration of PV database on the topic of data input, analytics, and issues. • Speakers would share their update, experiences and suggestions on the data collection and data input to the Database. |
| 12.15 | Q&A |
| 12.30 | Lunch |
| 13.30 | <p>Group Breakout: Database Sustainability Strategies</p> <ul style="list-style-type: none"> - Briefing for Break-out session - The outcome of this session was to identify solutions for project operation and continuity. Participants would be divided into 2 groups to discuss details of the following sub-topics: <p>Group 1: Network – Collaboration, Activities Group Chair: Dr Sulaiman Bin Shaari, Malaysia Group Secretary: Dr Sulak Sumitsawan, Thailand</p> <p>Group 2: Resources – Facility, Equipment, Capacity Building, Funding Group Chair: Dr Ahmad Maliki bin Omar, Malaysia Group Secretary: Dr Hathaithip Sintuya, Thailand</p> |
| 15.30 | Coffee Break |
| 16.00 | <p>Way forward for Small and Medium PV System Database in the APEC Region with Questions and Answer Session Chair: Dr Sulaiman Bin Shaari, Malaysia</p> <ul style="list-style-type: none"> - Based on the group discussion during the breakout session, representatives from each group would present their ideas and conclusions. A way forward for the operation of the project would be determined. |

| Agenda | |
|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 17.00 | Wrap up Session Chair: Dr Worajit Setthapun, Thailand - The session chair will provide feedback and recommendations on issues, database structure, analysis, and reporting. All the feedback will be compiled for troubleshooting. |
| 18.00 | Welcome Dinner |

Workshop 2 Participants

There were 32 participants attending the workshop from 11 economies. The female gender ratio was 34.3% with 11 female participants and 21 male participants. The gender aspect was considered to provide both speakers and participants with female participation.

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Workshop 2 Content and Outcomes

Presentations

For the opening ceremony, Mrs Munlika Sompranon, Director of Energy Cooperation Section, Department of Alternative Energy Development and Efficiency, Ministry of Energy provided the opening address. She stated that the outcome from the first workshop provided way forward to develop the PV System database for the on-grid and off-grid PV systems in the APEC region. This APEC project provided a very useful platform to share information for the better understanding of the PV systems in various APEC region. Since each APEC economy set their renewable energy target, therefore, PV systems had been installed quite quickly to achieve the goal. Sharing information on best practices of on-grid and off-grid PV systems was therefore very challenging, but it was also extremely useful to help assist the existing systems and the move of PV penetration in the same direction.

Dr David Parlevliet from the School of Engineering & Information Technology, Murdoch University, Perth, Australia was the Keynote Speaker. He shared his experience on the IEA PVPS Task 13. There were already existing PV databases for Performance, PV Fault Report Portal, Solar PV Map. Most of the data were from developed economies with online monitoring systems. However, there were still limited data sources and there was a need for Asia and hot/humid climate data for the global data sets. Therefore, this project APEC PV database could compliment with the IEA database. He reiterated that getting statistically significant data was challenging. Therefore, the ease of use for the database was very important. The data visualization and ease of access was the key to the database. The automated approaches would yield the most data where most of the data were from government agencies. To improve the quality of the database, the high-quality data sets could answer many questions such as performance in different climate and system longevity – long term performance and reliability.

For the invited speaker, Dr Nor Zaini Ikrom Zakaria from the Faculty of Applied Sciences, Universiti Teknologi MARA, Malaysia discussed about the Small and Medium Scale PV System Data Collection and Analysis. She recommended that the data and collection method should be in alignment with the IEC 62446 Grid Connected photovoltaic systems – Minimum requirement for system documentation, commissioning tests and inspection and IEC 61724 Photovoltaic system performance monitoring – guidelines for measurement, data

exchange and analysis. Assoc Prof Dr Chun-Liang Tung from Department of Information Management, National Chin-Yi University of Technology, Chinese Taipei focused on the Database, Data Analytics, and Data Utilization for PV Systems. He also suggested that the data monitoring device were necessary to record quality data in the stable manner. Wireless, low cost, stable long-range monitoring devices should be developed and installed on the off-grid PV sites. Analyzing the data could utilize Cloud Computing/ Hierarchical Dynamic Bayesian network – determine false alarm in monitoring system, Big Data Analytics – Machine Learning – as the useful analytic tools for data analysis.

The Project Update and Sharing of Experiences were from the project team members from 5 economies. The speakers shared the progress of the project and demonstration of PV database on the topic of data input, analytics, and issues. Also, they shared their update, experiences and suggestions on the data collection and data input to the Database. Dr Eko Adhi Setiawan, Indonesia; Dr Ahmad Maliki bin Omar, Malaysia; Dr Sulak Sumitsawan, Thailand; Dr Dung Phan Quoc, Viet Nam; and Ms Staci Sadoyama, United States were the representative from the 5 economies. The PV data from 45 sites were uploaded to the PV database at “www.apecpv.cmru.ac.th”. Most of the speakers indicated that the database was easy to use. However, it was time consuming to manually input and upload the data file for 1 day at a time. They suggested that the database should have some quality control protocol to determine good quality data. The standard unit, range of data, time format, time zone should be reevaluated. For the analysis and reporting of the data, the database should focus on more detailed and include the Performance data, Performance ratio, Energy Storage, Power Factor, kWh, Location Site Mapping/ Geographical View, and PV structure. CO₂ Emission Computations from the PV systems could also benefit the user. In the future, energy consumption data and Algorithm for Forecasting could also be included. For the way forward, this database should use IEC 61724 standard and build upon IEA PVPS Task Force. Data sharing agreement should also be clarified to ensure the proper usage of the PV data.

Breakout Session

Group Breakout session focused on Database Sustainability Strategies. The outcome of this session was to identify solutions for project operation and continuity. Participants were divided into 2 groups to discuss details of the following sub-topics:

Group 1: Network – Collaboration, Activities

Group Chair: Dr Sulaiman Bin Shaari, Malaysia

Group Secretary: Dr Sulak Sumitsawan, Thailand

Group 2: Resources – Facility, Equipment, Capacity Building, Funding

Group Chair: Dr Ahmad Maliki bin Omar, Malaysia

Group Secretary: Dr Hathaithip Sintuya, Thailand

Group 1: Network – Collaboration, Activities

For the sustainability of the database, the activity should focus on increasing the awareness and benefit of the database. The database should define specific purpose for the stakeholder such as Policy maker/ government/ academia/ research. There were a lot of challenges regarding the proprietary technology and business strategy to hinder data sharing. Therefore, collaboration activities could also include the Policy; Awareness; and Corporate Social Responsibility. To build upon this APEC project, other topic of collaborations could be:

- Remote Island Grid to address the technical issues as Joint Research and APEC Activities
- Socio-Economic Issues to address the PV system relations with improve socio-economic activities, common factors/category on socio-economics
- Gender related activities; women promotion of renewable energy
- Harmonizing Documents focused on standard of documents for economies

Group 2: Resources – Facility, Equipment, Capacity Building, Funding

For the Facilities & Equipment, the Data sharing should start with Universities with their own monitoring system because the university could share the data without the limitation of propriety. Therefore, the university network could provide the central database. Each economy had their own capacity building programs and funding such as:

- Philippines: Local Government could provide funding for local training
- Indonesia: University could invite expert for training
- Chinese Taipei: Government paid 50% for training for PV home users
- Thailand: Government provide training to local government officer that got support from DEDE
- Australia: Government training

- Korea: Call center to provide support

For the way forward, the objective of the database should be clarified. The data sharing depended on the agency policy. The data could be categorized as 3 types of data: General, Economy Monitoring System, Detailed Monitoring System. The database could be linked to the economy monitoring system such as the Malaysia. Data could also be collected from the non-governmental associations such as the Indonesia. It was very important to group and analyze data based on similar sites for reporting.

Summary of 2 Breakout Sessions for Way-forward with the APEC PV database

Based on the discussion during the workshop and breakout session, the specific aim of the PV database should be clarified, because different data sets could benefit different stakeholders. For the sustainability strategy of the database, existing network should be utilized for data collection such as EGNRET Network, IEA database, APERC, CSR, Industry Associations, and Government Monitoring. In this work, Phase 1 was completed with set up of database as data collection platform. The participants also suggested more joint activities. In Phase 2 of this project, Capacity Building with the support of HNEI, University of Hawaii could be the way to create awareness and best utilize the database. For Phase 3, continuation for data collection from other economies would provide more benefit for the APEC region.

Workshop 2 Picture

Opening Session



Keynote Address and Invited Presentations



Group Breakout





Wrapping Up Session



Database Page Structure

Based on the conclusion of the first workshop in Chiang Mai on 26-27 September 2016, the project team from Thailand developed the PV system database under the Chiang Mai Rajabhat University server host www.apecpv.cmru.ac.th. The components of the database comprised of Homepage, Registration page, PV data display page, and Data management page.

Homepage - The homepage showed the summary of the information from the database. Figure 1 showed the example of the PV database homepage. The map showed the PV systems site location from the database. The project information was also indicated in the homepage. The goal of this database was to be the open access online database to share data for the promotion and implementation of renewable energy.

PV Data Management Page - PV System data could be uploaded to the Data Management page. Figure 2 showed the input page for the General Information of the PV system which were data for Tier-1. The user could manually type the information into the field. For Tier-2 or Monthly PV data, the user could input the total power generation, averaged voltage, current and the ambient conditions. Inputting data for Tier-3 or Daily PV Data was more difficult. The data must be upload in the form of CSV format. The usual .csv data file would be for the PV system performance, irradiance, ambient temperature, and module temperature from the data logger. The user could select which to upload, depending how much they would like to share. Appendix I provided the PV Database Instruction Manual. The details instruction of how to input the data for each level were described.

PV Data Display Page showed the list of 3 Tier data for all PV system sites (Figure 3). The data were separated into 3 levels and the user could click to see the data as General PV Data, Monthly PV Data, and Daily PV Data. After clicking on General PV data button, the PV system basic information would be shown as 4 groups of information such as General, System, Geographical, Application/Financial (Figure 4). Figure 5 showed the Monthly PV data which was the system operational data. It was intended for the institutional network to update the operation data monthly. The data comprised of Electrical Data such as total power generation, average voltage, and average current. Ambient condition data such as irradiance, ambient temperature and module temperature, wind velocity and amount of rainfall for that

month could also be recorded. The data for the third level was the Daily PV Data or Detailed Performance data collected from the data logger. The data must be upload as .csv file and in this page, the user could click to download the .csv file (Figure 6). For ease of display, the user could click and the graph of operation for the selected date would appear (Figure 7).

Another function was also added for sharing real-time data in the database (Figure 8). For example, Chiang Mai Rajabhat University commissioned the 702 kW PV system - on-grid which was supported by the Ministry of Energy, Thailand. Real-time data monitoring system and the data could be shared as open access. Figure 9 displayed real time monitoring for the 702 kW sites in Chiang Mai. Real time voltage, current, power, irradiance, ambient and module temperature were shown as open access.

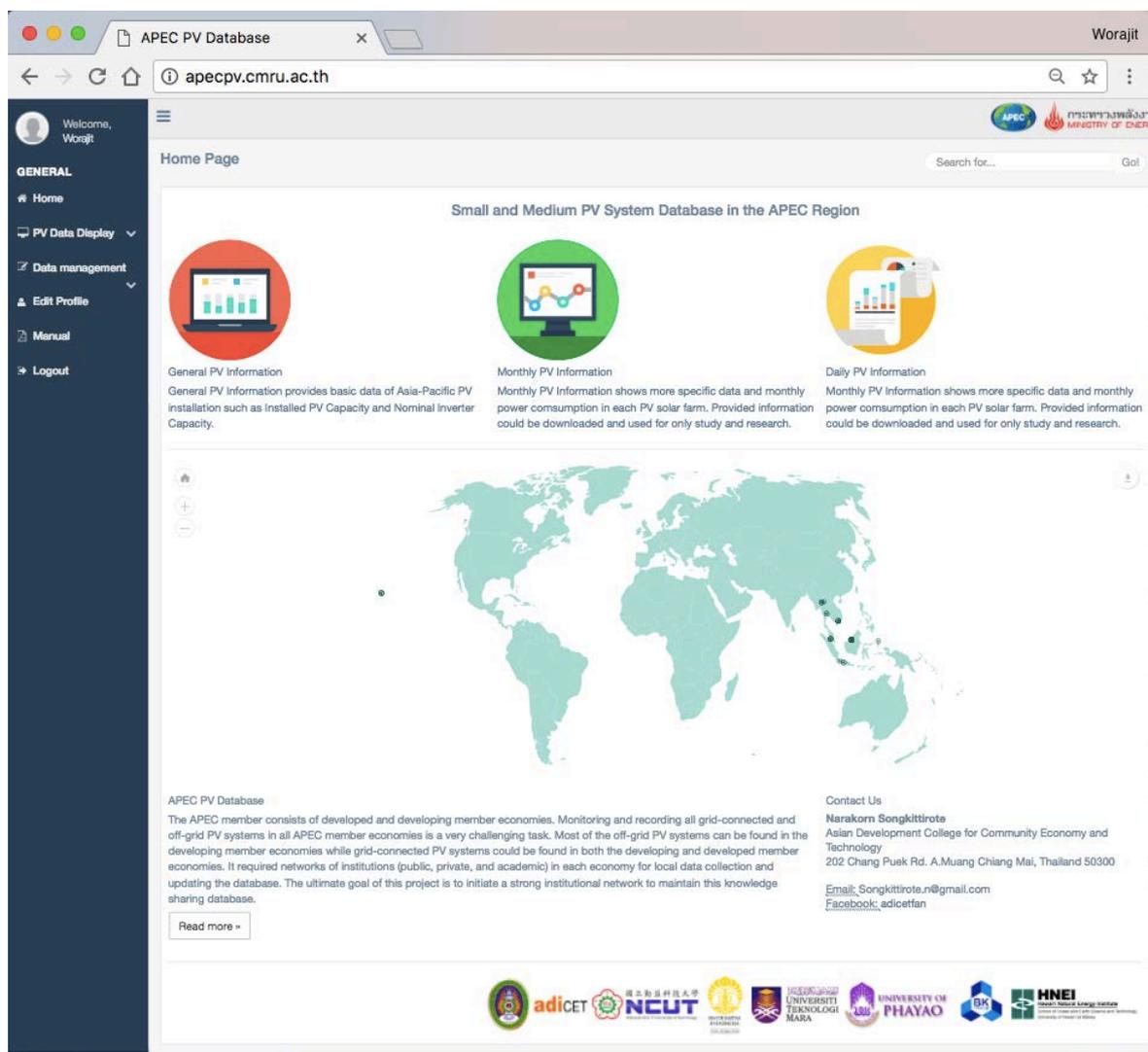


Figure 1. Homepage

General PV Data: Input General information of PV System

Please add the general information of the PV systems

PV System Name*

Economy/Country* Thailand

City*

Date Commission*

Grid-Connected/Off-Grid* Grid-Connected

Module type* Monocrystalline

Installed PV Capacity* kWp

Nominal Inverter Capacity* kW

Funding Source Private, Government, etc.

Figure 2. Data input page for Tier 1- General information of PV systems

List of Small and Medium PV System Database in the APEC Region

Data sharing platform for Small and Medium Scale PV systems in the APEC Region: Please click for PV System Data in General, Monthly and Daily PV Data

Show 50 entries

| Economy | PV System Name | Size (kWp) | Grid-Connected/Off-Grid | General PV Data | Monthly PV Data | Daily PV Data |
|-----------|--------------------------|------------|-------------------------|---------------------------|---------------------------|---------------------------|
| Indonesia | IFC Rooftop | 26 | Grid-Connected | View Data | View Data | View Data |
| Indonesia | Kolorai Island | 1.86 | Off-Grid | View Data | View Data | View Data |
| Indonesia | JATENGSO6 | 15 | Off-Grid | View Data | View Data | View Data |
| Indonesia | MALS11 | 50 | Off-Grid | View Data | View Data | View Data |
| Malaysia | UITM-GERC Mono System | 9 | Grid-Connected | View Data | View Data | View Data |
| Malaysia | UITM-GERC Poly System | 5 | Grid-Connected | View Data | View Data | View Data |
| Malaysia | UITM-GERC Thin Film | 1 | Grid-Connected | View Data | View Data | View Data |
| Malaysia | Teikok Melano | 66.3 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Anur Dalam | 56 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Long Semadoh Naseb | 106.92 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Long Kajang | 69 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Lusung Laku, Balanga | 226.8 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Long Sukang, Lawas | 238.14 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Rumah Dau Sri Aman | 129 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Bario Central | 887 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Long Lellang Bario Baram | 127 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Long Peluan Bario Baram | 69 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Long Seridan Bario Baram | 112.32 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Pa' Dalih Bario Baram | 108 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Pa' Lungan Bario Baram | 69.12 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Pa' Mada Bario Baram | 48.86 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Pa' Remudu Barion Baram | 40.32 | Grid-Connected | View Data | View Data | View Data |
| Malaysia | Sungai Tunoh | 288.12 | Off-Grid | View Data | View Data | View Data |
| Malaysia | Nanos Janan | 164.64 | Off-Grid | View Data | View Data | View Data |

Figure 3. PV Data Display Page

The screenshot shows a web browser at the URL `apecpv.cmru.ac.th/basicdetails.php?id=25`. The user is logged in as 'Worajit'. The main content area is titled 'General PV System Data' and displays the following information:

| UiTM-GERC Mono System | |
|--------------------------------------|-----------------------|
| General | |
| PV System Name: | UiTM-GERC Mono System |
| Economy/Country: | Malaysia |
| City: | SHAH ALAM |
| Date Commissioned: | 2012-04-17 |
| Grid-Connected/Off-Grid: | Grid-Connected |
| Funding Source: | Private |
| System | |
| Module Type: | Monocrystalline |
| Installed PV Capacity: | 9 kWp |
| Nominal Inverter Capacity: | 8 kWp |
| Peak Sun Hour: | 4.7 h |
| Battery Type: | - |
| Battery Capacity: | - |
| System Voltage (DC): | - |
| Inverter Nominal Rating (AC): | - |
| Auxiliary Generator Type: | - |
| Auxiliary Generator Capacity: | - |
| Geographical | |
| GPS: | 3.068734, 101.496945 |

Figure 4. General PV System Data (Basic Information)

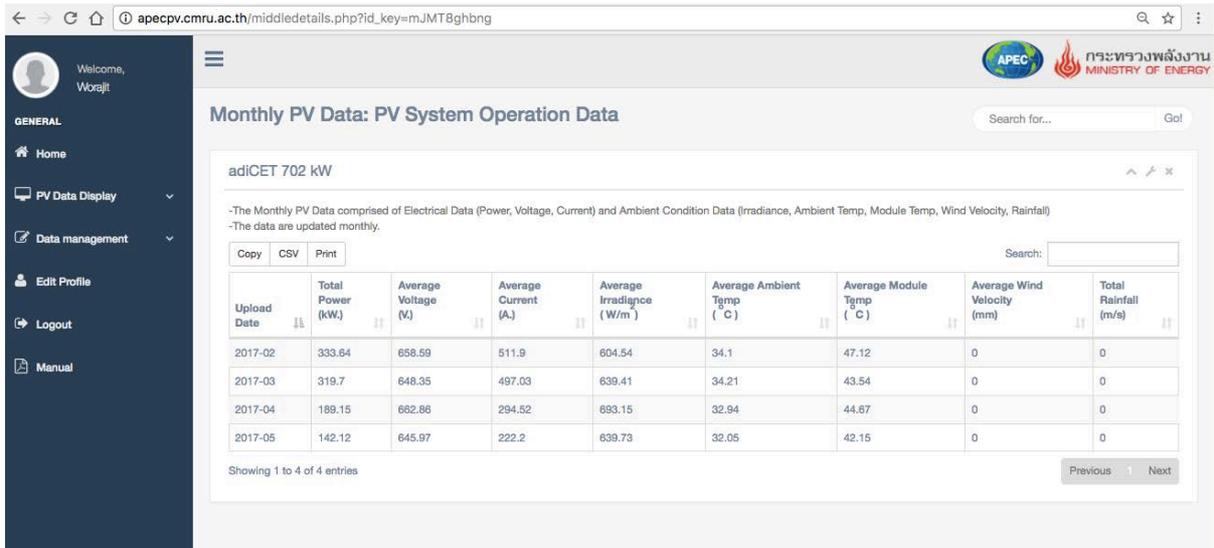


Figure 5. Monthly PV Data - PV System Operation Data

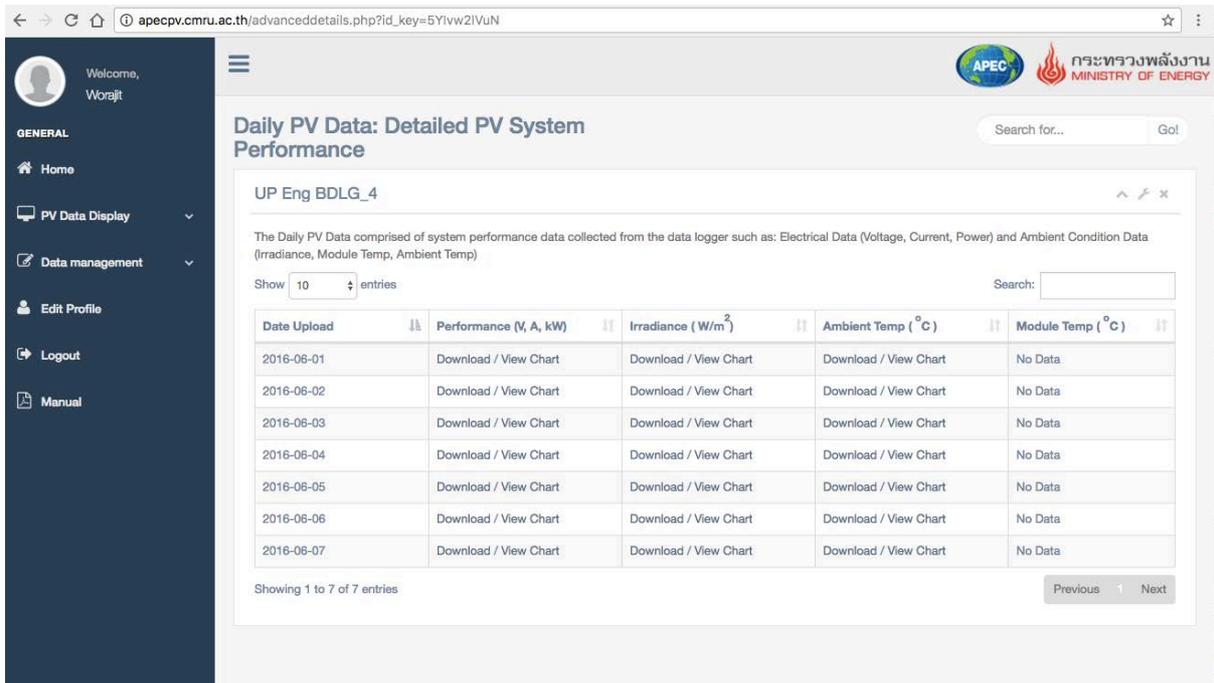
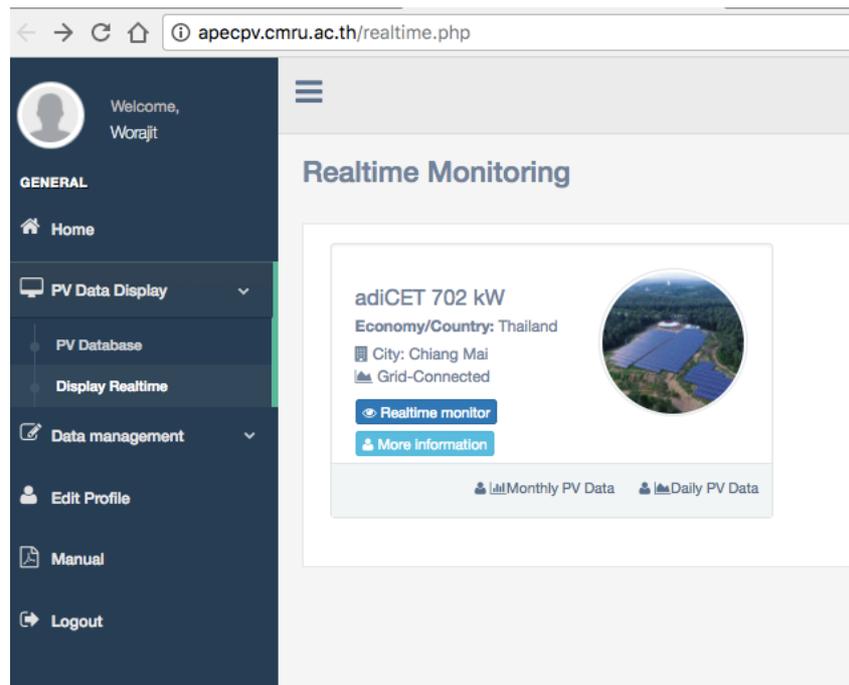


Figure 6. Daily PV Data – Detailed PV System Performance



Figure 7. Examples of Daily PV Data Graph



**Figure 8. Real-time Monitoring –
Linked to PV 702 kW Monitoring System at Chiang Mai, Thailand**

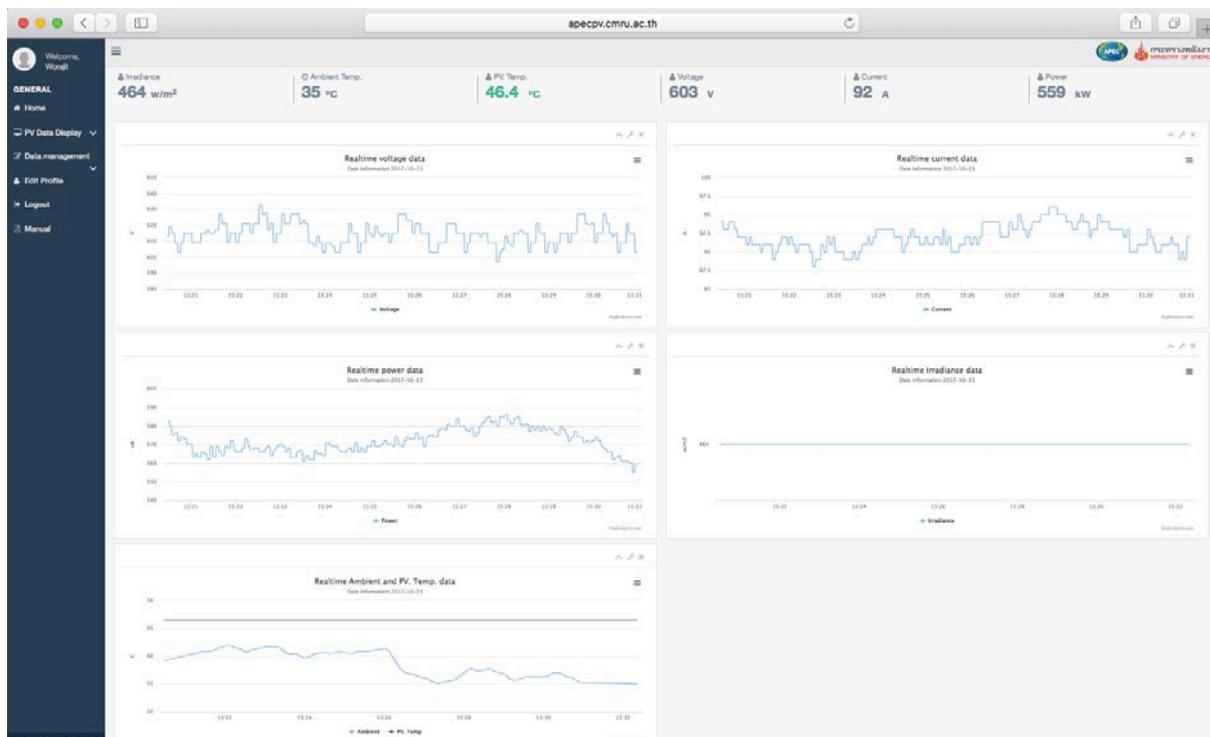


Figure 9. Real-time Monitoring from Data Logger

Issues regarding the database usage were notified to the web developer and were solved such as: streamline the data field; ease of use; data display issues; connection issues; server issues; data compatibility issues, etc. Various data from the data logger were tested for the database to find the best solution. The database was tested for the data from the Thailand's selected site in the initial web development. Then, the online portal was tested with the other four economies: Indonesia, Malaysia, United States and Viet Nam. In this work, data from 45 on-grid and off-grid PV systems were uploaded to the database. The project team from each economy shared their database usage experience during Workshop 2. They also provided further suggestions and recommendation enhance the usability and benefit of the database during the workshop.

Conclusion

Monitoring and recording all PV systems in all APEC member economies was a very challenging task. It required networks of institutions (public, private, and academic) in each economy for local data collection and updating the database. In this project, five economies participated: Indonesia, Malaysia, Thailand, United States and Viet Nam. There were two workshops held in Chiang Mai, Thailand on 26-27 September 2016 and Tokyo, Japan on 23 October 2017. The workshops were led by expert members with tailored program for experience sharing, brainstorming and collaboration. The workshop included several sessions with varying dynamics such as expert presentations, case studies discussion, and group breakout discussion. The focus of the workshop was brainstorming ways forward for data sharing of the PV system under the database platform.

Workshop 1 provided guideline for Data Collection and Compilation; Processing, Analysis and Updating Database Methods; and Database Structure, Reporting, Maintenance and Sustainability. The data would be categorized into 3 tiers: 1) General Information (no data logging), 2) Monthly Data (kWh, Solar Irradiation, etc.): averaged per month, 3) Detailed Performance: 1-10 min data logger. It was determined that the project consultant, Chiang Mai Rajabhat University, was responsible to develop the database and coordinate between the participating economies.

In this project, data from 45 PV system sites from 5 economies were input into the database. The data were in the form of general data, average monthly performance data and

very detailed performance daily data. Due to the variety of data format from each site, the participating economy and the database host trouble-shooted the database website together. Due to proprietary information for many of the PV sites, the University network in this project provided the information for the 45 sites that could be shared.

The second workshop provided the venue for sharing of experiences in using the online platform. Mainly the recommendations were such as the need for data quality control, standardize unit and time, easier way to input data and file size limitation. Suggestion from APEC economy representatives and the invited speakers were also provided to make the database more useful such as the database could focus on Performance data, Performance ratio, Energy Storage, Power Factor, kWh, Location Site Mapping/ Geographical View, PV structure, CO₂ Emission Computations, Energy consumption data and Algorithm for Forecasting. The project should develop the data sharing agreement of how the data could be used shared. Other suggestions and comments were such as the current existing database from IEA provided Performance, PV Fault Report Portal, and Solar PV Map, however, it still lacked the data from Asia hot/humid region. There was opportunity for APEC database to be integrate with the IEA database. However, the database should be simple and not too complicated for data input. During the data collection, the alignment in standard should be used such as IEC 62446 (Grid Connected photovoltaic systems – Minimum requirement for system documentation, commissioning tests and inspection) and IEC 61724 (Photovoltaic system performance monitoring – guidelines for measurement, data exchange and analysis). Low cost and wireless long-range data monitoring devices should be implemented for off grid systems. The collected data should be analyzed with big data analytics and machine learning to automatically report the useful information for the stake holders.

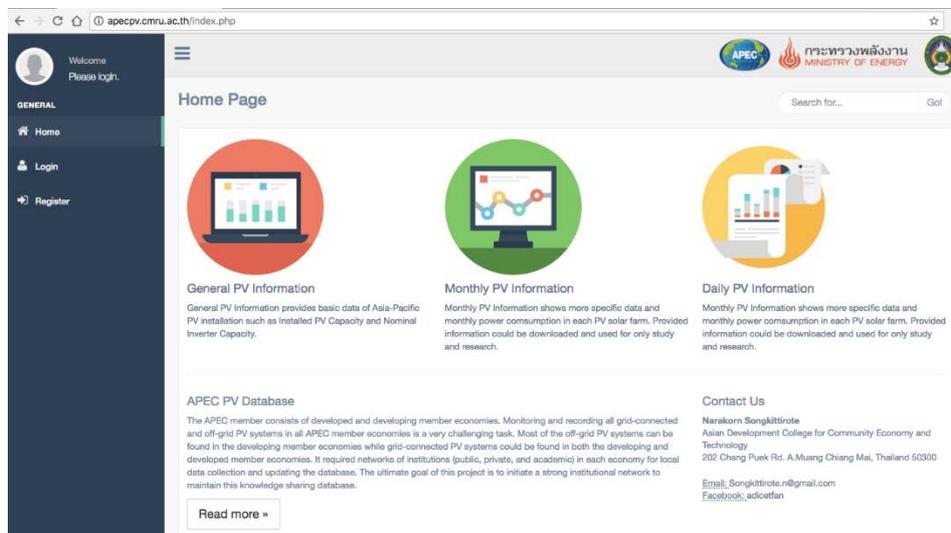
The way forward for the PV database should be to increase the awareness and the benefit of the database; using existing network for data collection. The university network system should be the central coordinating party starting from the university own PV systems and the systems that the university provided academic service. Then, the database should be built upon the network with EGNRET Network, IEA database, APERC, CSR, industry associations, government monitoring. The database should also have parts that define specific purpose of stakeholder: Policy maker/ government/ academia/ research. With the clear and more specific aim, the benefit to the stakeholders could be realized.

PV Database Instruction Manual

Database Website: <http://www.apecpv.cmru.ac.th/>

A. Registration

1. Go to <http://www.apecpv.cmru.ac.th/> and select register.
2. Please fill in all the information. (Note: If you get an error on the password choice, please use a long and complicated password.)
3. Click Submit, please remember your username and password.

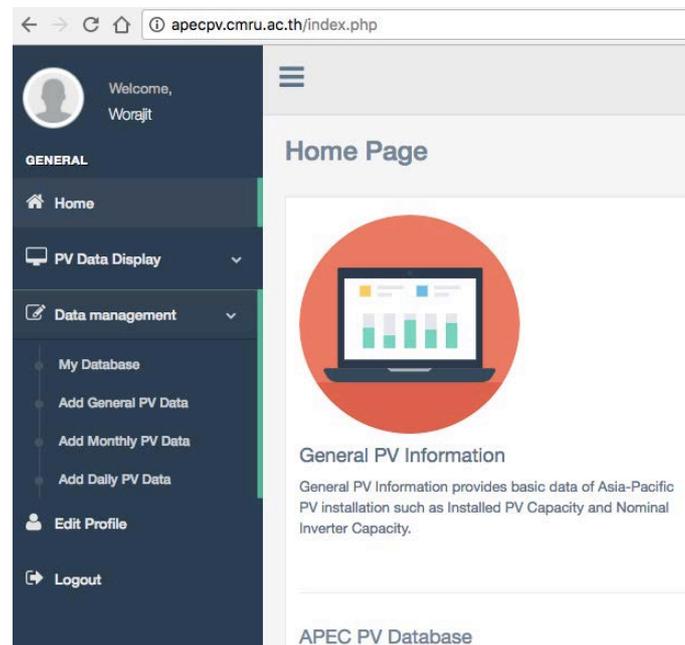


Register

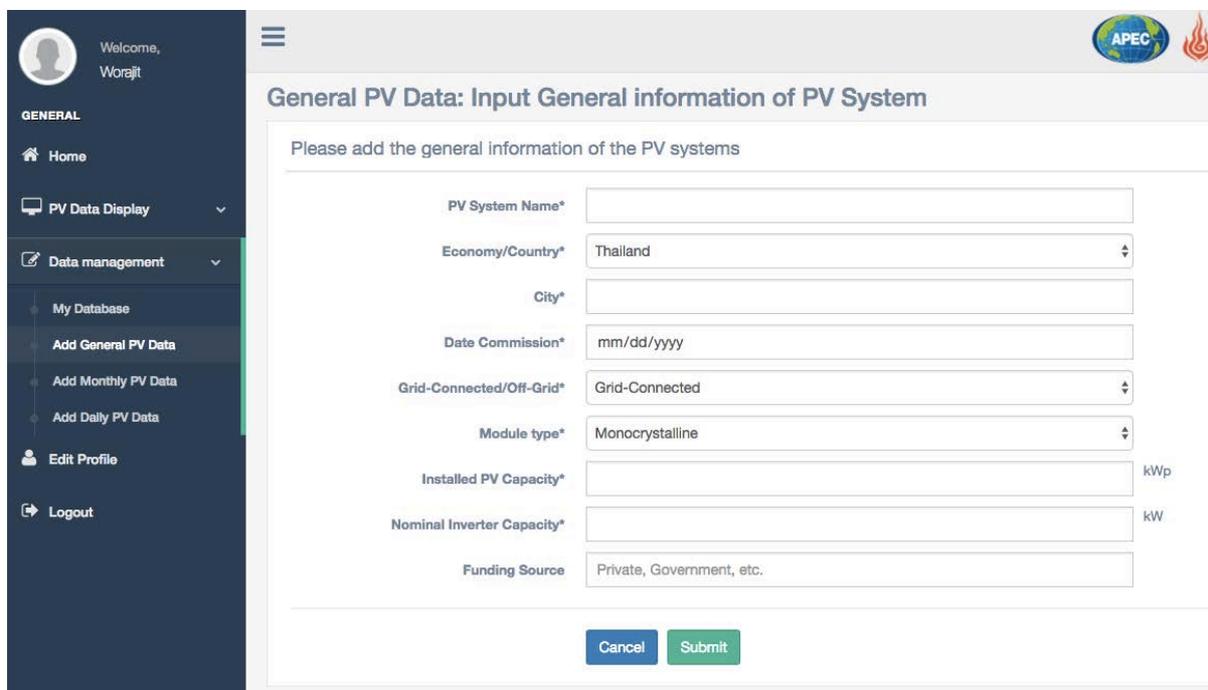
| | |
|-----------------------|--------------------------|
| Name Title* | Dr. |
| Full Name* | both name(s) e.g Jon Doe |
| Email* | |
| Confirm Email* | |
| Website URL* | www.website.com |
| Username* | |
| Password* | |
| Repeat Password | |
| Telephone | +66832232001 |
| Country* | |
| Name of Organization* | |
| Position | |
| Address* | |

B. How to add the PV System Site information: General Data

1. Go to Data management > click on Add General PV Data

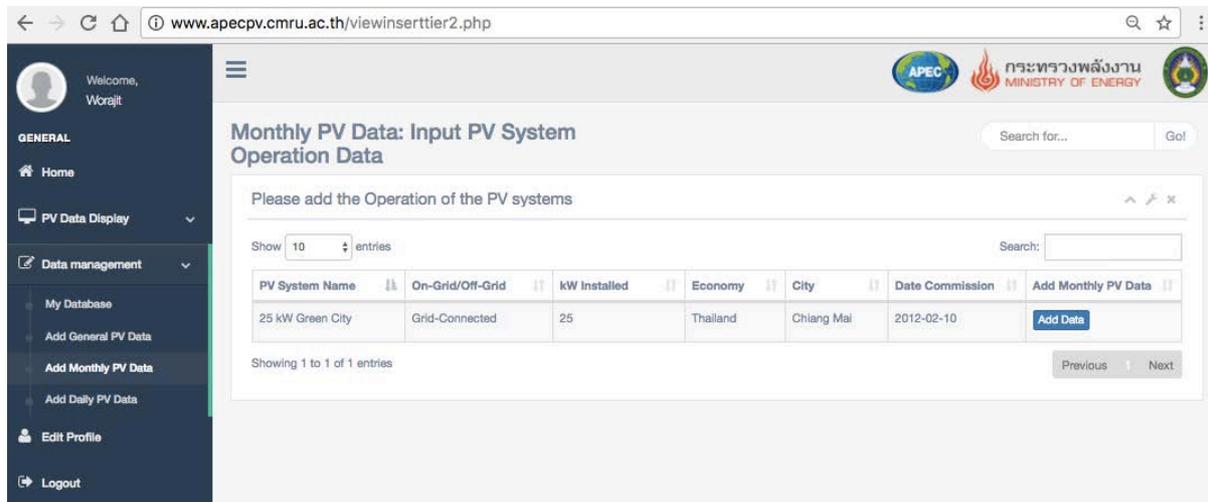


2. Fill in the information of your PV systems. Please fill with the information you can share.

A screenshot of the 'General PV Data: Input General information of PV System' form. The form is titled 'Please add the general information of the PV systems'. It contains several input fields: 'PV System Name*' (text input), 'Economy/Country*' (dropdown menu with 'Thailand' selected), 'City*' (text input), 'Date Commission*' (text input with placeholder 'mm/dd/yyyy'), 'Grid-Connected/Off-Grid*' (dropdown menu with 'Grid-Connected' selected), 'Module type*' (dropdown menu with 'Monocrystalline' selected), 'Installed PV Capacity*' (text input with unit 'kWp'), 'Nominal Inverter Capacity*' (text input with unit 'kW'), and 'Funding Source' (text input with placeholder 'Private, Government, etc.'). At the bottom of the form, there are two buttons: 'Cancel' and 'Submit'.

C. How to add Monthly Data

1. Go to Data management > Add Monthly PV Data
2. Select button add data in Blue



www.apecpv.cmru.ac.th/viewinserttier2.php

Welcome, Worajit

GENERAL

- Home
- PV Data Display
- Data management
 - My Database
 - Add General PV Data
 - Add Monthly PV Data
 - Add Daily PV Data
- Edit Profile
- Logout

Monthly PV Data: Input PV System Operation Data

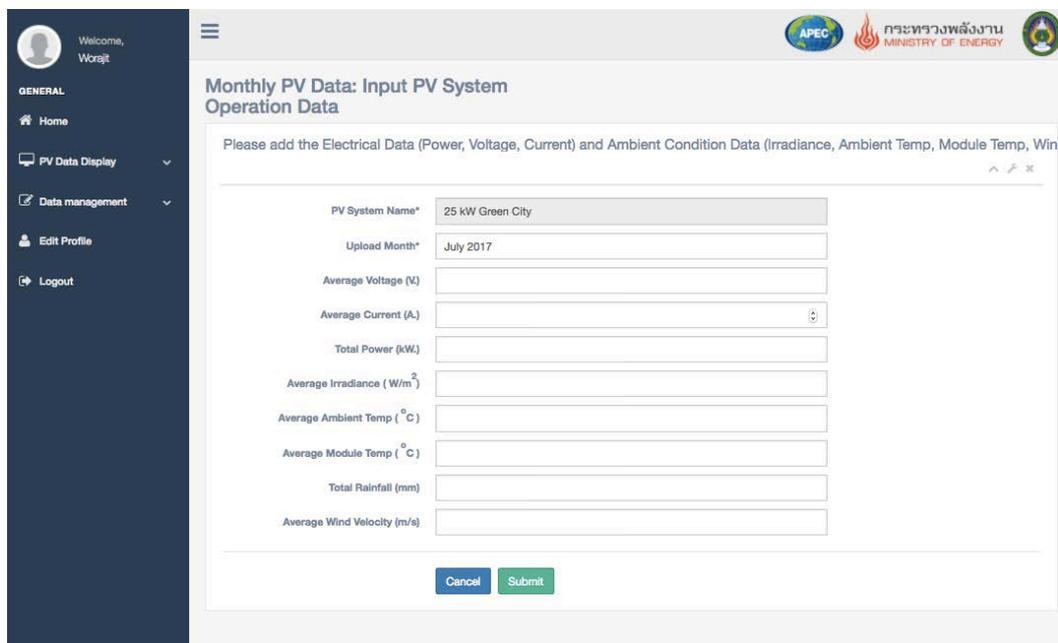
Please add the Operation of the PV systems

Show 10 entries Search:

| PV System Name | On-Grid/Off-Grid | kW Installed | Economy | City | Date Commission | Add Monthly PV Data |
|------------------|------------------|--------------|----------|------------|-----------------|---------------------|
| 25 kW Green City | Grid-Connected | 25 | Thailand | Chiang Mai | 2012-02-10 | Add Data |

Showing 1 to 1 of 1 entries Previous Next

3. Select the month that you want to upload data [Upload Month*]
4. Type in manually, the average data for that month.
5. Leave the data blank if you don't have the data.
6. Then, click submit



Welcome, Worajit

GENERAL

- Home
- PV Data Display
- Data management
- Edit Profile
- Logout

Monthly PV Data: Input PV System Operation Data

Please add the Electrical Data (Power, Voltage, Current) and Ambient Condition Data (Irradiance, Ambient Temp, Module Temp, Wind)

PV System Name* 25 kW Green City

Upload Month* July 2017

Average Voltage (V)

Average Current (A)

Total Power (kW)

Average Irradiance (W/m²)

Average Ambient Temp (°C)

Average Module Temp (°C)

Total Rainfall (mm)

Average Wind Velocity (m/s)

Cancel Submit

D. Daily Data

1. Go to Data management > Add Daily PV Data
2. Select button add data

The screenshot shows a web application interface for managing PV system data. The page title is 'Daily PV Data: Input PV System Performance Data'. A sidebar on the left contains navigation options: Home, PV Data Display, Data management (selected), My Database, Add General PV Data, Add Monthly PV Data, Add Daily PV Data, Edit Profile, and Logout. The main content area displays a table with the following data:

| PV System Name | On-Grid/Off-Grid | kW Installed | Economy | City | Date Commission | Add Daily PV Data |
|------------------|------------------|--------------|----------|------------|-----------------|-------------------|
| 25 kW Green City | Grid-Connected | 25 | Thailand | Chiang Mai | 2012-02-10 | Add Data |

Below the table, it indicates 'Showing 1 to 1 of 1 entries' and provides 'Previous' and 'Next' navigation buttons.

3. Follow each step's instruction
4. Step 1: Add upload date: Please input the date of the data you would like to upload. Then press submit.

The screenshot shows the 'Tier 3: Input PV System Performance Data' page. The page title is 'Tier 3: Input PV System Performance Data'. The main content area displays a form for adding data for '25 kW Green City'. The form includes a message: 'Please add date for the daily performance data.' and a progress bar with five steps:

- Step 1: Add Upload Date
- Step 2: Upload Electrical Data File
- Step 3: Upload Irradiance Data File
- Step 4: Upload Module Temp Data File
- Step 5: Upload Ambient Temp File

The form also includes input fields for 'PV System Name*' (25 kW Green City) and 'Upload Date*' (mm/dd/yyyy). At the bottom, there are 'Cancel' and 'Submit' buttons.

- Step 2: Upload the PV Performance data as Voltage, Current Power
- Please make a CSV file with format as follows: Column A – Date; Column B – Time; Column C – Voltage (V); Column D – Current (A); Column E – Power (kW)

| | A | B | C | D | E |
|----|----------|---------|------------|------|-------|
| 1 | Date | Time | PV Voltage | PV i | PV kw |
| 2 | 17/05/23 | 0:00:00 | 4 | 0 | 0 |
| 3 | 17/05/23 | 0:00:05 | 4 | 0 | 0 |
| 4 | 17/05/23 | 0:00:10 | 4 | 0 | 0 |
| 5 | 17/05/23 | 0:00:15 | 4 | 0 | 0 |
| 6 | 17/05/23 | 0:00:20 | 4 | 0 | 0 |
| 7 | 17/05/23 | 0:00:25 | 4 | 0 | 0 |
| 8 | 17/05/23 | 0:00:30 | 4 | 0 | 0 |
| 9 | 17/05/23 | 0:00:35 | 4 | 0 | 0 |
| 10 | 17/05/23 | 0:00:40 | 4 | 0 | 0 |
| 11 | 17/05/23 | 0:00:45 | 4 | 0 | 0 |

- Click choose file. Go and select your CSV file and click upload.
- Then click submit.

Electrical Data (Date, Time, Voltage, Current, Power)

Please upload Electrical data as .csv file.
Column 1: Date; Column 2: Time; Column 3: Voltage (V); Column 4: Current (A); Column 5: Power (kW)

Step 1: First step description | **Step 2: Second step description** | Step 3: Third step description | Step 4: Fourth step description | Step 5: Fifth step description

Please select file* No file chosen

9. Step 3: Upload the Irradiance as W/m²
10. Please make a CSV file with format as follows: Column A – Date; Column B – Time; Column C – Irradiance (W/m²)
11. Click choose file. Go and select your CSV file and click upload.
12. Then click submit.

Irradiance (Date, Time, Irradiance)

Please upload Irradiance data as .csv file.
Column 1: Date; Column 2: Time; Column 3: Irradiance (W/m²)

Step 1
First step description

Step 2
Second step description

Step 3
Third step description

Step 4
Fourth step description

Step 5
Fifth step description

Please select file* Choose File No file chosen

Upload File

Cancel Submit

13. If you don't have Irradiance data, please click cancel, and it will go to the next step.
14. The process is the same for Step 4 for Module Temperature and Step 5 for Ambient Temperature

APPENDIX II: Summary of Evaluation Forms

APEC Project Evaluation Result The 2nd APEC Workshop on Small and Medium PV system Database in the APEC Region

| Statement | Strongly Agree | Agree | Disagree | Comment |
|--------------------------------------------------------------------------------------------|----------------|---------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The objectives of the training were clearly defined. | 81.25 % | 19.75 % | 0 % | - Some objective is not clear to some parties e.g. policymaker, private sector. - Very clear objectives - Well and clear |
| The project achieved its intended objectives. | 62.5 % | 38.5 % | 0 % | - Permission issues still need to be discussed. - Yes, but could be enforce further. - Some need to be done on population the database. - Feedback from user are useful to further improvements to simplify facilitate inputs. |
| The agenda items and topics covered were relevant. | 75 % | 25 % | 0 % | - These linked well to the topic |
| The content was well organized and easy to follow. | 75% | 25 % | 0 % | - Well organized |
| Gender issue were sufficiently addressed during implementation. | 56.25 % | 44.75 % | 0 % | - Good gender balance - I do not quite understand what criteria to answer this question- participants. |
| The trainers/experts or facilitators were well prepared and knowledgeable about the topic. | 75 % | 25 % | 0 % | - Very useful sharing knowledge with economies which are empowered with the database |
| The materials distributed were useful. | 62.5 % | 38.5 % | 0 % | - Available in soft copy and can be downloaded. - Those were organized. |

| Statement | Strongly Agree | Agree | Disagree | Comment |
|----------------------------------------------------|----------------|-------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The time allotted for the training was sufficient. | 38.5% | 62.5% | 0% | <ul style="list-style-type: none"> - Need more focus & specific topic in 1 workshop - Yes, meet the objectives - Sufficient, but those topics are always benefit from more time. - Technically sufficient to get on overview but more time is needed at operational level |

1. How relevant was this project to you and your economy?

5 Very 62.5 % 4 Mostly 38.5 %

- We have own national monitoring system which is similar.
- We need to learn the progress and development of PV technology in respective economy.
- Useful to all APEC region
- Excellent. Should continue with next phase.
- Chinese Taipei's aim to have solar PV installations of 3.1 GW. In the workshop, we can understand the progress in other economies and learn experiences from the workshop.
- Ties in Australia & IEA projects. We need more data in this region & this project will set the gap.
- To conduct meaningful analysis critical to support of stakeholder interest across multiple levels, whether industry and academic, quality data is essential. This project focuses on the heart of that reality.
- Database in small and medium PV system is not well-established yet.
- This project is useful to learn the performance of PV system in many economies so we can learn the different performance which comes from different areas in each economy.
- The database is definitely very useful. Compensates and benchmarking are to be taken positively towards improvement.

2. In your view what were the project's result achievements?

- Still a lot of work to convince or approach economies to participate & share the data
- Sharing defund date though portal and discuss about the technology with respective economy
- Just starting of next movement
- Building the APEC database in the near future
- Achieved to meet the aim & objectives well done to team from CMRU, Thailand.
- Implementations' and practical popularity of a PV database in this region
- Many result from project e.g. collaboration between economies database developed experience, and PV system progress in economies
- It facilitated the information exchange, knowledge and experience sharing and key data elements imported to during PV development and integration to power system and participating economies. It is important foundational work to achieve PV development objectives.
- Collaboration are showing of insight and information on the topic.
- Achieve for starter point, we get the good database.
- Excellent in terms of commitment by the project members!! To be here from zero level. However, there are some uncontrollable permeants - invalid data, not enough data -> more time are needed -> more harmonization of data.

3. What new skill and knowledge did you gain from this event?

- Database designing solar energy evaluation PV database and PV system monitoring.
- Insights of data needs and realities in respective economy
- Database utilization
- Awareness of gender & socio-economic
- Facilitating international experts
- Differentiation the circumstance in APEC
- Can have lesson learned from other economies with similar conditions
- Analytical process
- Knowing the states of development from other economies and lesson learned and always beneficial
- Collaboration from each economies and sector
- Constraints and limitation of setting date from each economy
- New trends of cooperation
- Specific information on PV systems in the APEC region

4. Rate your level of knowledge of and skill in the topic prior to participating in the event

Very High 12.5 % High 31.25 % Medium 31.25 % Low 25 %
Very Low 0 %

5. Rate your level of knowledge of and skill in the topic after participating the event:

Very High 25 % High 56.25 % Medium 18.75 % Low 0 %
Very Low 0 %

- Ideas on collaboration with the other member economies and with different stakeholders
- I learnt new aspect aspects of the technology that are critical but non-technical
- Involved with on different ways that economies handle data on PV (Small and Medium) systems. Explore to apply some policies in data management perhaps about comment policies that are effective.
- Noted the concern and the sensitivity issue
- Involvement of government in participating and providing data to the database especially on sharing of data
- This is my field of expertise but it is always good to get more information.

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

- Sharing the information to the policy makers and other stakeholders
- New system for expend of renewable energy
- Develop work strategies & organizes trainings
- Will communicate & initiate links with the new institutions I now know
- Join the database
- Improve design parameters used in training in GCPV and also OGPV system design
- The knowledge gained from the workshop can be used for increasing accuracy of a real-time PV monitoring system
- Analyze data & develop new proposal
- How to make the project more attractive and interactive
- Trainings, new procedure, develop work plans/strategies
- This project has developed new relationships to be leveraged
- Hopefully linking the APEC, APVI, and IEA data sets together room for future collaboration and project

7. 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?

- Continued finding & support for the regional database
- Key next steps were identified in workshop results for action
- To provide additional data showing at various levels
- Budget/ fund to sustain the project
- A follow-up on specific project (site) in order to apply database collaboration and management
- Expanding the database to more valuable and meaningful information so that it can be shared by each economy
- Enlarge the database
- Yes, APEC should fund the next phase for the project. See report as final copy.
- Joint – researches in terms of universities
- System integration
- Developing the methodology for monitoring system with IOT and other new technology (Web based, real time, etc.)

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

- Some work on dissemination & data utilization. This will come as more information is placed in the database.
- International funding for similar project could be requested for supporting the program.
- Need more face-to-face meetings more often. Difficult to have meetings via email.
- Clear objective which could benefit all sector and benefit
- The level of confidentiality on type of data should have been identified. If whether is to find the best technology for specific environment (as we are not all size fits all), or methodology of economies with common context. Attribute in term of climates, geography etc.
- Doing further analysis on the defund database so that it become useful for comparative performance incites