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Recommendations on Deploying SPESS for Energy-Resilience in Disaster-Stricken APEC Community

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Executive Summary

Disaster mitigation, relief and prevention are key issues for almost every APEC member economies, especially in areas that experience not only natural disasters such as floods, typhoons and earthquakes, but also power outages on the local, regional and multi-state areas. The concept that solar power will assist disaster relief has been around for decades, and there have been increasing improvements in the implementation of renewable energy into disaster management. Among numerous developed and under developed solutions for those areas, solar-powered emergency shelter solutions (SPESS) are a natural and wise selection for disaster affected victims and communities because of its sustainable, stand-alone operation capabilities and other potential benefits.

From preliminary workshop and research, SPESS team think that there is an exciting opportunity for the development of integrated solar energy and emergency shelter solutions to assist distressed communities affected by natural disaster. Renewable energy has a valuable role to play in the reduction of emissions but it can also play a greater role in combatting one of the greatest effects of looming climate change in the form of more frequent and violent disasters.

Shelter design is well understood and there are many competitive products in the marketplace. Use of solar panels is increasingly employed, but the greatest weakness is integrated easily deployed solutions. The SPESS project can make a difference to people lives and livelihoods by re-establishing communities through the provision of shelter and energy. SPESS team hope this recommendations could make contributions to the development of energy and disaster relief management work in APEC region.

Recommendations on Deploying SPESS for Energy-Resilience in Disaster-Stricken APEC Community (EWG 22/2015A)

Project Description and Background

SPESS project endeavours to foster cooperative efforts in developing SPESS to strengthen the wider APEC community's energy-resilience & sustainability affected by natural disasters, thereby contributing to APEC 2015's priority area of "Building Sustainable and Resilient Communities"[1].Catastrophes in our region — such as

- 2005 Hurricane Katrina,
- 2008 Earthquake in China's Sichuan province,
- 2010-11 Queensland Australia floods & 2011 Thailand floods,
- 2011 Great East Japan Earthquake and the ensuing tsunami,
- 2012 Superstorm Sandy in US,
- 2013 Super Typhoon "Haiyan" hitting eastern Philippines,

——are important reminders of the severe situation APEC community faces.

When natural disasters hit and conventional grid-based energy supply is severely disrupted, SPESS is capable of being quickly deployed on-site, providing displaced victims with the much-needed emergency shelters as well as a reasonable amount of energy from integrated solar energy systems (e.g. PV is integrated into the shelter's roof). From this perspective, SPESS also offers a new arena for low carbon renewable measures (like solar) to be integrated into an overall (power-grid for normal time & SPESS for disaster-relief time) energy-resilient and sustainable power infrastructure. For a post-disaster community facing relatively long-term recovery, interconnected SPESS could even form micro-grids to sustain community rehabilitation [2].

This project will establish two workshops to engage key APEC stakeholders/experts and an SPESS open/crowdsource innovation competition to tap into APEC community's knowledge base for a more diverse perspective, culminating in the development of “Recommendations on Deploying SPESS for Energy-Resilience in Disaster-Stricken APEC Community”.

Project Objectives

The SPESS Project Objectives are:

- To promote low-carbon energy technology innovation in APEC, through advancing the integration of solar energy and emergency shelter technologies in the development of SPESS;
- To improve capacity of APEC stakeholders (especially those from developing members) in adopting science-based approaches for emergency preparedness and post-disaster response, through harnessing an innovative, low-carbon, energy-resilient technology of SPESS; and
- To develop Recommendations on deploying SPESS that responds to the varying climatic, economic and cultural conditions of APEC member economies, helping bring low-carbon energy measures into the mainstream of APEC’s science-based Disaster Management framework.

SPESS Recommendation Aim and Objectives

This recommendation aims to provide information on the potential application and case reference of SPESS within the APEC Community. Specifically, this report aims to provide:

- Recommendations based on SPESS Literature;
- Recommendations based on SPESS open innovation competition;

This recommendations informs APEC forum Energy Working Group (EWG), specifically its sub-forum of Energy Resilience Task Force (ERTF) and Expert Group on New and Renewable Energy Technologies (EGNRET).

Recommendations based on SPESS Literature Survey

Introduction of SPESS Literature Survey

Background:

Developing Solar-Powered Emergency Shelter Solutions (SPESS) contributes to building an energy-resilient APEC community through secure and sustainable energy supply along with emergency sheltering for disaster victims in dire needs during disaster relief period. The relevant APEC Energy Working Group project is titled "Developing Solar-Powered Emergency Shelter Solutions (SPESS) as an Energy-Resilience Tool for Natural Disaster Relief in APEC Community" with an APEC project number of EWG22 2015A. In order to assess the status quo among the APEC economies, literature survey on the current practice of emergency sheltering and its energy supply in APEC community as well as available technologies/solutions in this field are needed to be summarized.

Objectives of the Project/Tasks:

- To provide the status quo assessment on the current practice of emergency sheltering and its energy supply in APEC economics (Australia; Brunei Darussalam; Canada; Hong Kong, China; Japan; Republic of Korea; New Zealand; Singapore; Chinese Taipei; The United States).
- To provide candidate technology catalogue of the available/potential technologies/ solutions relevant to the field of SPESS(e.g. solar energy systems suitable for mobile application, various types of mobile/prefab/foldable structures that can be used as emergency shelters/mobile housing in post-disaster relief, and the already proposed/existing SPESS/SPESS-like schemes/designs).
- To provide the list of recommended stakeholders to be involved in SPESS project, including individuals/organizations from the research & industry sectors of APEC/Non-APEC economies (e.g. those who are involved in the development of existing SPESS/SPESS-like schemes/designs and SPESS-relevant technologies).

Outputs of SPESS Literature Survey

SPESS literature survey [3] was completed by Mr. Neil Greet from Collaborative Outcomes Pty Ltd, and this report had been upload to the APEC publication database and circulated in both EWG and EPWG members. For more detailed information of this report, please visit APEC website (the URL is http://publications.apec.org/publication-detail.php?pub_id=1746).

Generally, this literature survey sets out to provide information on the potential application of SPESS within the APEC Community. Specifically, this report aims to provide:

- An understanding of the user need within the international disaster management framework (Understanding the requirement);
- A snapshot of comparable developments to SPESS outside APEC (Understand wider applications);
- An assessment of SPESS like capabilities across 12 APEC Economies (A capability assessment);
- A technology and candidate based assessment (Examine capability assessment); and
- A snapshot of other considerations for the SPESS project (Understand wider context).

Besides, this report concludes that there is an exciting opportunity for the development of integrated solar energy and emergency shelter solutions to assist distressed communities affected by natural disaster. The four mature integrated solar and emergency shelter solutions are:

- IKEA Better Shelter identified in Case Study 3 but not an APEC economy.
- US Military Armed Forces Camp design in Afghanistan identified in Case Study 4.
- Mege shelters from China.
- Daiwa Lease from Japan.

Also, there are a number of conceptual shelter designs which incorporate solar energy across APEC economies. Here is the observations based on the current practice in emergency shelters and energy supply (assessment by APEC economy)

- Australia has some local emergency shelter design experience, with small innovations but most shelter expertise resides largely in industry and NGOs. Australian government organizations and academic universities do have some world leading solar research capability. There is no evidence of research into integrated emergency shelter and solar energy in Australia.
- Brunei Darussalam has no local emergency shelter design experience, and no multinational shelter base. The University of Brunei Darussalam has some limited solar research capability. There is no evidence of research into integrated emergency shelter and solar energy in Brunei Darussalam.

- The Philippines has a desperate need for improved shelter and energy solutions to improve disaster response capabilities. Case Study 1 highlighted some of the innovations taken after the destructions of Typhoon Haiyan. There is some local emergency shelter design experience, with small innovations but most shelter expertise resides largely in industry and NGOs. There is very limited solar research capability and no evidence of research into integrated emergency shelter and solar energy in the Philippines.
- Canada has a well-developed local emergency shelter design experience, with significant innovations and industry capacity. The Canadian government has explored the use of solar energy to support remote communities with some solar research capability and there is a commercial solar industry. There is no evidence of research into integrated emergency shelter and solar energy in Canada.
- Hong Kong, China has the Asia Disaster Preparedness Institute which is focused on medial preparedness, but may provide scope through the Harvard Humanitarian Initiative to examine shelter and energy considerations. There is limited local emergency shelter design innovations to support international disasters. There is some world leading solar research capability, but no evidence of research into integrated emergency shelter and solar energy in Hong Kong, China.
- China has enormous industrial capacity with shelter and solar PV production. China is currently the leading supplier of UNHCR tents. The Mege shelter has a limited integrated emergency shelter and solar energy capability. Industrial research in solar energy has enormous potential to continue to provide improvements for the next decades. There are also smaller innovative designs in both shelter design and solar energy which are available and could be exploited by the SPESS project.
- Japan has a well-developed shelter capacity with some world leading innovations. The Diawa House EDV-01 shelter has an integrated emergency shelter and solar energy capability. Selected research in solar energy will contribute enormously to future development of renewable energy in Japan.
- Korean emergency shelter has been focused on military application but is developing excellent domestic innovations. There is enormous potential in the solar research of Korean Industry such as Hyundai and LG Electronics. There is no evidence of research into integrated emergency shelter and solar energy in Korea.

- New Zealand has limited local emergency shelter design experience, and relies on multinational shelter agencies based in New Zealand or Australia for emergency shelter capability. New Zealand has some solar research capability at Universities of Waikato and University of Auckland. There is no evidence of research into integrated emergency shelter and solar energy in New Zealand.
- Singapore has limited local emergency shelter production capability bit some world leading innovative niches. Singapore is conducting world leading solar energy research through Singapore Solar Energy Research institute, but there is no evidence of research into integrated emergency shelter and solar energy in Singapore.
- Chinese Taipei has limited local emergency shelter production capability. The Chinese Taipei Industrial Technology Research Institute (ITRI) is conducting world leading solar energy research, but there is no evidence of research into integrated emergency shelter and solar energy in Singapore.
- The United States has enormous industrial capacity with shelter and solar pv production. There are a number of innovative shelter designs that integrated emergency shelter and solar energy capability. Solar research is world leading with NREL research providing a basis for other industry led innovations. The US DOE Solar Decathlon project in its international form could be exploited by the SPESS project.

Recommendations based on SPESS Literature Survey

This report points out that shelter design is well understood and there are many competitive products in the marketplace. Use of solar panels is increasingly employed, but the greatest weakness is integrated easily deployed solutions. The key lessons taken from the understanding of disaster management and the case studies is that a further research developments of solar energy in disaster relief shelters must demonstrate these characteristics:

- Solar solution must be applicable and is not the answer by itself. Complimentary energy solutions and diversity of solutions is required.
- Solar is lightweight and easily deployable. Factors to consider are not only power/$, but power/mass and power/volume.
- Solar supply chain management must be developed in advance of the disaster through UN and host governments.
- Standard solar connections are critical to simple construction. Standard connections to shelter and water purification must also be part of the solution.

- Given the nature of the disaster response the solar panels with the best 'sun test' are necessarily required. Simple maintainable solutions are the best.
- Solar tracking introduces mechanical complexity and is not a key requirement.
- Improved storage systems will advantage solar applications in disaster relief.
- A solar energy deployment to a disaster cannot be the first time a traumatized population has seen the technology as it will not be trusted.
- Solar energy must be scalable, depending on the extent and location of damage. For instance, the needs difference between rural storm damage and city earthquake.

Also, this report recommends that SPESS project needs consider several other issues in the project:

- An Energy Resilient Tool, Resilience is the capacity of a system, community or society to adapt to disturbances resulting from hazards by persevering, recuperating or changing to reach and maintain an acceptable level of functioning. Resilient capacity is built through a process of empowering citizens, responders, organizations, communities, governments, systems and society to share the responsibility to keep hazards from becoming disasters. Resilience minimizes vulnerability; dependence and susceptibility by creating or strengthening social and physical capacity in the human and built-environment to cope with, adapt to, respond to, and recover and learn from disasters.

  From an energy perspective efforts centre on power system resilience, with resilience defined as the ability of a power system to withstand a major disruption with limited degradation and to recover within a narrow time frame with constricted costs. The goals of resilience engineering are a reduced likelihood of damage to critical power systems and components, limited consequences of failures on society, and reduced time to supply recovery. There is no doubt that power system performance will be diminished when a major disaster strikes, but adequate countermeasures and response plans can help the system to return to its original functionality. Resilience not only depends on equipment, building codes, and technology but more so on the organization and standardized emergency preparedness of well-structured electricity companies.
- Building Smart and Resilient Cities, APEC Cities are at risk from disaster with half the region's people live in urban areas, and by 2050 that proportion could rise above two-thirds. Many cities already struggle to provide basic services such as roads, water

supplies, and sewage disposal, leaving the poorest people, especially those in slum areas, highly exposed to sudden shocks. Around 740 million city dwellers in Asia and the Pacific are now at 'extreme' to 'high' disaster risk − often living in multi-hazard hotspots that are vulnerable to cyclones, earthquakes, floods and landslides.

APSEC sponsors this project but it is important to note that employment of SPESS has an opportunity to provide 'build back better' opportunities that will support the wider goals of building smart and sustainable cities. There is the opportunity to create an important self-correcting feedback loop across the APEC economies by combining 'build back better strategies with 'smart and sustainable' cities.

Complimentary to APSEC's 'smart and sustainable' cities is the Rockefeller Foundation 100 Resilient Cities (100RC) which is dedicated to helping cities around the world become more resilient to the physical, social and economic challenges that are a growing part of the 21st century. 100RC supports the adoption and incorporation of a view of resilience that includes not just the shocks—earthquakes, fires, floods, etc.—but also the stresses that weaken the fabric of a city on a day to day or cyclical basis. Examples of these stresses include high unemployment; an overtaxed or inefficient public transportation system; endemic violence; or chronic food and water shortages. By addressing both the shocks and the stresses, a city becomes more able to respond to adverse events, and is overall better able to deliver basic functions in both good times and bad, to all populations.

- Understanding Governance, A resilient energy system requires efficient governance, where the level of governance matches complexity. A system which is over governed is a fragile but robust system and is likely to be expensive and uncompetitive, while too little governance leads to a fragile and brittle system which is highly likely to fail catastrophically. Resilience aims to avoid either circumstance occurring and sound management is always required to keep complex systems in balance between the two extremes.

  A broad range of policies will be needed to unlock the considerable potential of solar energy. They include establishing incentives for early deployment, removing non-economic barriers, developing public-private partnerships, subsidizing research and development, and developing effective encouragement and support for innovation. New business and financing models are required, in particular for up-front financing of off-grid solar electricity and process heat technologies in developing economies.

Unfortunately, energy governance and policy development across APEC is an extraordinarily complex arrangement with some arrangements being too restrictive and in other areas non-existent.

- Building Investment and Partnerships, Business and private sector organizations are starting to go beyond their traditional exercise of 'corporate social responsibility' through philanthropic donations to NGO, to become involved as direct actors in disaster management. Many APEC member economies and several UN humanitarian organizations, such as World Food Programme (WFP) and OCHA, have contracted private sector organizations to provide logistic and transport support to their humanitarian efforts. By way of example, DHL has response teams established in Singapore for the Asia region that can be deployed to a disaster affected economy to help organize the handling and warehousing of relief supplies. DHL entered a partnership agreement with UN OCHA in December 2005. There is no reason that similar long term partnerships should not be established with solar and shelter companies.

  Research relationships with industry and academic institutions in the APEC are essential to improving disaster management. Business provides pathways to commercial technologies such as improved deployable communications or early warning systems. The rich diversity of academic institutions within the economies of the APEC could be utilized not only for research and development, but to supplement appointments with various disaster organizations and institutes.
- Enhancing Humanitarian Innovation. The International Humanitarian Network has recognized that many organizations have not taken advantage of recent innovations in other field. UNHCR continues to draw inspiration from its history and tradition, but is equally committed to finding creative and innovative solutions to settlement and shelter problems that improve the wellbeing and dignity of refugees in a changing world. Meeting these challenges requires the continuous modernization of working methods and application of new and innovative technologies and construction materials. In recent years, considerable efforts have been made to improve the quality and types of settlement and shelter designs. UNHCR has engaged with its partners in efforts to develop new concepts for settlement design, the improvement of technical specifications for tents, development of self-standing tents and accessories, such as winterization kits, and the testing of new shelter prototypes. Other initiatives include

the development of mobile phone applications for site planners, and tools for assessments that integrate GPS technology. To make this research more effective, UNHCR and its partners within the sector, will explore collaborations with the private sector and professional associations, such as architect boards, and will expand existing dialogue with universities.

UNHCR has launched a variety of “designing a home” thematic competitions aimed at developing creative pilot projects for alternative shelter solutions while regular market surveys ensure that UNHCR is continually updated on the availability of new shelter products. Modern technology can also be applied to traditional solutions, enhancing the durability of culturally-acceptable options. With increasing interconnectivity and interdependence, UNHCR will explore ways of creating platforms, networks and communities of practice that enable sharing knowledge and expertise on thematic issues and innovative approaches. UNHCR will also enhance dialogue with the donor community so as to ensure that investment in research and development is supported.

Recommendations based on SPESS Open Innovation Competition

Introduction of SPESS Open Innovation Competition

As one of the most important activities of SPESS project, SPESS open innovation competition has been successfully organized by APSEC and this activity was started from 1 September 2016 and ended on 31 October 2016. We encourage governments, enterprises and individuals from APEC communities or other regions who are interested in presenting their ideas to participant in this competition and submit high quality works. During the competition, Female participants were strongly encouraged to involve in together with male participants, thereby addressing APEC value of gender equity [4].

With the active supports from APEC Secretariat and APEC members, SPESS team collected four effective designs designed for the two target economy, i.e. Indonesia (Facing problems: Volcanic eruption, flood, landslides, typhoons and storms and are common disasters in Indonesia.) and Peru (Facing problems: Earthquake is one of the most frequent natural disasters in Peru.). All SPESS designs collected from this competition had been presented and shared at the Final APEC Workshop on SPESS. During SPESS workshop B which held on 28-29 July 2016 in Tianjin, China., about twenty delegates from 8 APEC economies (China; Indonesia; Malaysia; The Philippines; Singapore; Thailand; The United States of America; Viet Nam) exchanged SPESS-related information and held a warm discussion on the four excellent SPESS innovation designs (3D Puzzle Shelter and Accordion Shelter for Peru; Rainbow Home and The Harbour for Indonesia).Participants and experts from APEC region carefully reviewed and discussed each work during the workshop. Excellent works had been displayed at SPESS Open Innovation Competition website and exhibited at the workshop B.

Outputs of SPESS Open Innovation Competition introduction

As the core outputs of SPESS Open Innovation Competition, SPESS deigns were designed based on the different needs of victims and communities in different disaster scenarios, this part will introduce the four excellent designs submitted by citizens in APEC region and may provide references for the economies facing the similar disasters like Peru and Indonesia. For more information, please contact APSEC or directly visit SPESS Website [5].

Peru (one of the target area) is located in the subduction zone of Antarctica and American plate, which is one of the world's most active seismic zone. For this reason, Peru is an earthquake-prone economy in all APEC members. Continued crustal movement is a long-time presence, so it is necessary to build shelter to react to earthquakes. Besides, Lima, the capital, is a tropical desert climate, its weather is mainly mild and dry and the solar energy resource is abundant. Thus, Lima is suitable for and has the advantage of applying photovoltaic technology and deploying SPESS in disaster period.

Indonesia (another target area) have been hit by the typhoon in 1956, 2001 and 2004. The ongoing typhoon disasters not only bring their homes destroyed, but threat the life of local people. It is hot and rainy throughout the year in Bitung, and the annual average temperature and rainfall are about 26 degree C and 2000 mm respectively. Although Indonesia is located in the tropics, but most of the land is located near the equator. Due to the lack of ground turning force, Indonesia is almost not affected by the typhoon. But there are some rare cases, such as the 2001 landing on the Indonesian island of Sumatra typhoon vamei. Because of Indonesia's vast sea, humidity is about 70%.

3D Puzzle Shelter:

As to 3D Puzzle Shelter, the designers would like to design a temporary shelter that can be used for several months or years after earthquake before the reestablishment of the community.

Lima is the largest city of Peru at the latitude around 12S. Many large and small earthquakes occur around Lima every year. In history, several severe earthquakes hit Lima causing great loss. There are several slums on the mountains surrounding the city, where the residents suffer from bad living environment and high risk of earthquake. Residents, living in instable shanties on the sandy land, endure the lack of water and electricity. Once the earthquake hit the place, the situation would get worse. It is right the time to design a shelter for them to deal with the possible risks in the future.

The designers hold the opinion that architectural form should derive from environment and climate to solve the actual problems. The climate in Lima is quiet unique, compared by the other tropical desert climate at the same latitude. It shows a mild desert climate: neither cold nor hot, which temperature rarely fall below 14 degree Celsius or rise above 29 degree Celsius. Relative humidity is very high, causing persistent heavy fogs all year round. Even though, Lima has quiet high UV radiation. It is a good chance to make use of solar power. While humidity is high, rainfall is very low.

So the shape was gradually formed on the basis of climate. The cuboid is the fundamental form. Then I slant the wall at 102 degree to avoid too much sunlight in the hot summer. The roof inclines at 18 degree to make the PV more efficient by calculating. To cope with high humidity and heavy fog, relatively closed facade is suitable. Besides, wide open type performs badly on heat preservation in cool winter. As to the structure, the shelter calls for fast construction. The structure that the designers chosen, developed and modified is based on Wikihouse' design guild, and can be assembled within 1 day by 3 people.

As shelter, the full life circle should be considered thoroughly. First, all the components are made by 18 millimetres bamboo plywood cut by CNC machine. Bamboo is a local material and using bamboo rather than wood costs less. Then the components can be transported by helicopter or track to the spot. The construction of one shelter requires no professional building skill and can be finished by 3 people in one day. The rehabilitation phase usually last 2 years or so. After that, it can be transformed into permanent residence or just taken apart to transfer to other disaster hitting area.

Fig. 1 shows a pattern for 4-people family, which divided into 2 rooms, a bathroom and a kitchen. Based on the adaptability of components and the reversibility of joints, the shelter can be easily upgraded by extended into two directions to make a bigger one or apply to different usage, such as schools, clinic and chapel.

Taking into account the infrastructure had been seriously damaged after the earthquake. Especially the grid couldn't be restored timely and couldn't meet t power demand of residents living. So, the designers had designed an off-grid PV storage system to provide the necessary power for refugees (Fig.2). We choose energy-saving lamps as our lighting equipment, total power is 182 Watt. Monocrystalline silicon photovoltaic modules are used in the PV system, total capacity is 580 Watt. In addition to PV system, the designers also use solar hot water system to provide refugees with the necessary domestic hot water.

Fig. 1: Plan and elevation of 3D Puzzle Shelter (provided by the designers)

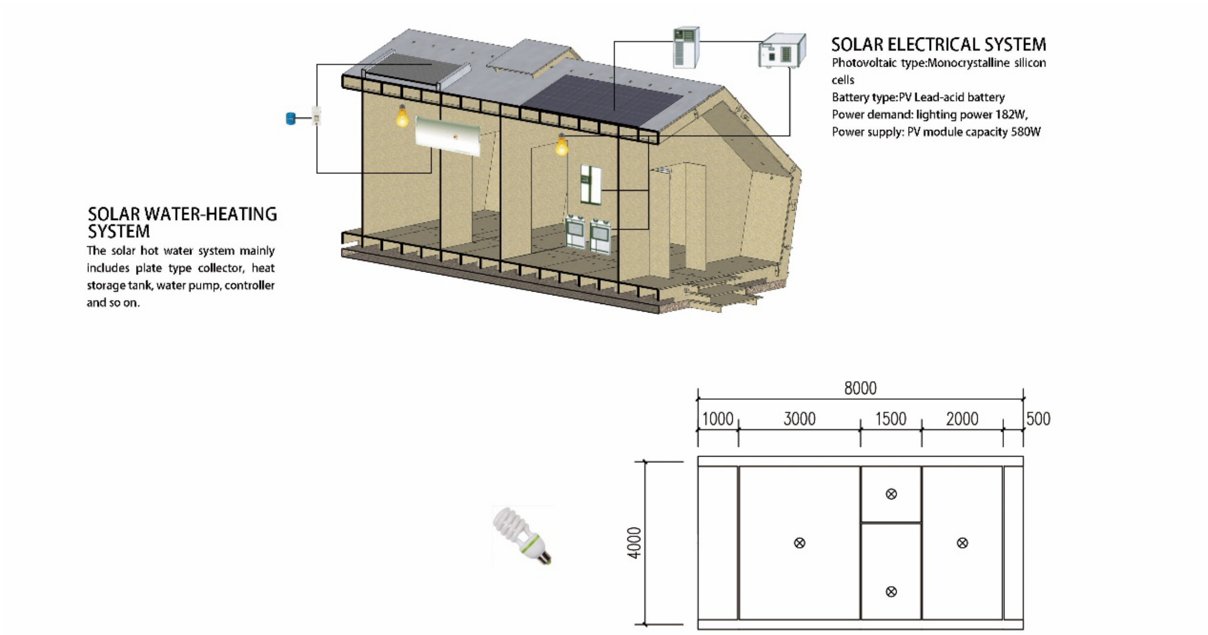


Fig. 2: Energy system of 3D Puzzle Shelter (provided by the designers)

Accordion Shelter

To design out a suitable SPESS for Lima, the designers of Accordion Shelter firstly think an issue about how to realize low-complexity-construction and humanized functions easily. To this end, the designers put a box in the centre of the shelter to realize the transformation. This box plays an important role in Accordion Shelter. As shown in the Fig. 3, the shelter is 4 by

6.5 meters in the plan. According to the different actual context conditions, the space in the central box can be changed into different private room or public room. The space on both sides can bear the accommodation of a family or so. Meanwhile, emergency relief supplies from other zones could be stored in the central box easily and transported by the same transport carriers in the same time before using.

After the basic design, indoor wind and day lighting analysing of accordion shelter is critical. And the simulation results are showing good in these suitable materials and structure. Material choosing for the shelter is important. They should better be adaptable, flexible, changeable in case of earthquake, and should also have fire-proof and water-proof capacity. Accordingly, bamboo is a suitable material for Accordion Shelter. Actually, Peru has been pushed the bamboo architecture standards. So the designers finally decided to use bamboo plywood as the material for the box, door and floor panel. At the same time, the shelter envelop is made of blue oxford cloth. Further, the roof provides the help for the shelter's energy producing, it can satisfy nearly all of the need inside.

After the structure design, the work of seismic analysis of the structure was done. Simulation results showing that the Accordion Shelter is able to withstand shock created by earthquake within the scope of design and the whole structure will not have obvious deformation.

Most disasters are accidental and unexpected, therefore the shelter construction process should be completed as soon as possible in order to ensure the safety and health of disaster refugee after the happening of natural disaster. In this respect, the main structure of Accordion Shelter is light steel, this determines that the time cost of unloading and installation process could be controlled at a reasonable range by only few people (see Fig. 4).

When it comes to the energy system, the designers of Accordion Shelter had carefully taken infrastructure damage like power grid failure into account after the earthquake. They have designed a standalone PV storage system for this shelter to provide the power supply for disaster refugees and disaster relief staff. The energy system for Accordion Shelter includes thin film photovoltaic modules, PV controller, battery, PV inverter, DC loads, AC loads and so on (see Fig.5).

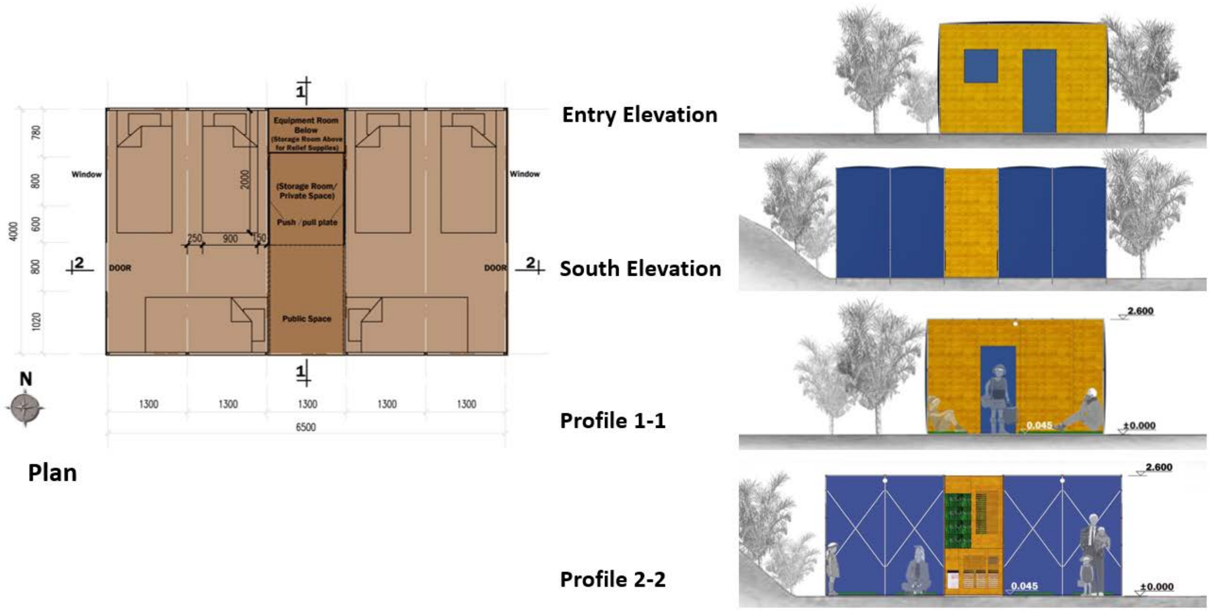


Fig. 3: Plan and elevations of Accordion Shelter (provided by the designers)

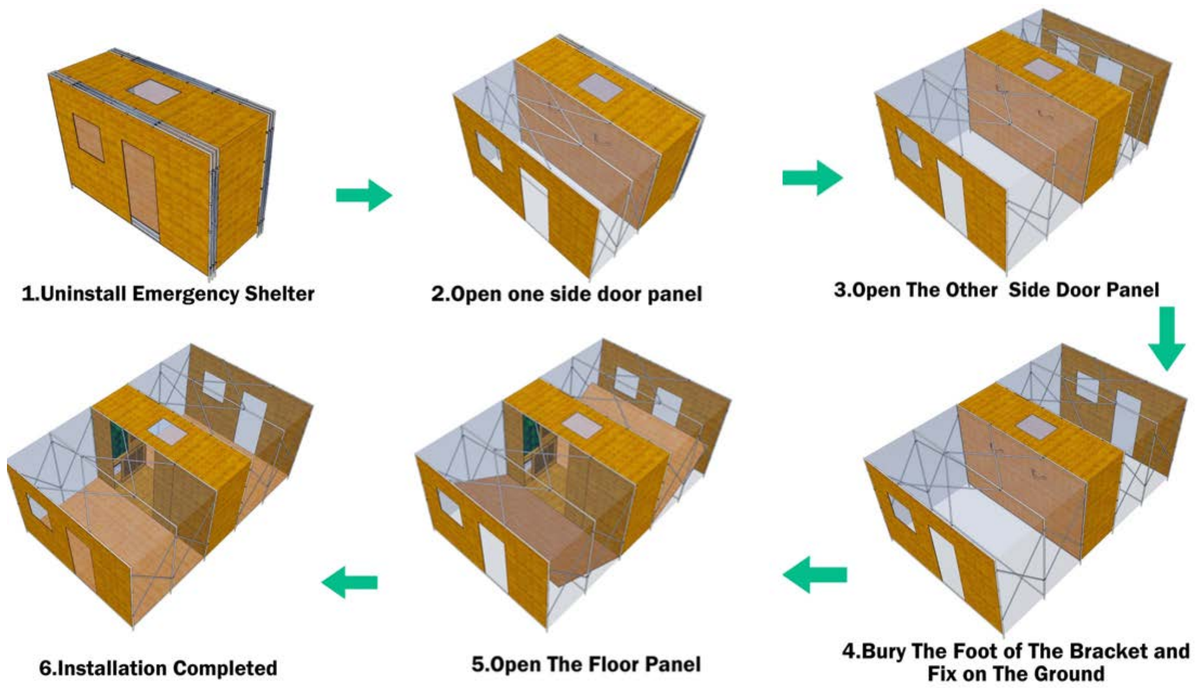


Fig. 4: Construction process of Accordion Shelter (provided by the designers)

Off-grid PV System

Device Selection Table

Device name	Specification	Quantity
LED lamp	12V/80W	2
LED lamp	12V/7W	2
Thin film PV modules	330W(battery capacity)	1
PV controller	12V/30A	1
PV lead – acid battery	12V/200Ah	3
PV inveter	12V-220V/300W	1
AC outlet	220V	

Fig. 5: Energy system of 3D Puzzle Shelter (provided by the designers)

Rainbow Home

Rainbow Home (see Fig. 6 and Fig.7) is designed for Bitung city, Indonesia. How to solve the living problem of local people properly, the gap between the refuges after the disaster and rebuild their homes quickly, become the key to solve the problem. It cannot be as simple as a tent, and also cannot like temporary housing needs a lot of time to build either. Obviously, the design inspiration of Rainbow Home come from the rainbow after the rain, like a bridge across the sky. The designers use colourful thin film PV module at the surface of the shelter to simulate the rainbow colours. The rainbow after the storm indicates and symbolizes the hope in the heart of local people after the natural disaster.

The design was inspired by a book opening and closing mode, not only can be folded in the process of transportation, reduce the volume, convenient transportation, be able to maximize the rapid expansion and complete function in the simple layout. The local people will have a small house for shelter as soon as possible. According to the design, this shelter could be transported to the local area, and 2 or 3 individuals can easily complete the installation process. When the reconstruction work of disaster area is completed, these shelter could be refolded easily, transported to other areas for reusing.

There are two different sizes of the building. The small building can accommodate 4-6 people which is used for a family or separate individuals. It only meets the requirements of the most basic life. And the big building is mainly used as a temporary public building, it can used as a small reading room, a temporary hospital which can accommodate six hospital beds or an operation room. Furthermore, they can be used together. In the small building, we can divide the space with a soft curtain to keep out the sight, to ensure the privacy of residents. Due to no sewage system around, there is only a simple washing room in the building. The sewage is directly discharged to the outside through the floor drain. We will set up a public lavatory. When the building as an operation room, doctors and nurses can have enough space for surgery, there are doors on both sides of the building, they are not only able to ventilation, but also meet the flow of people and waste lines do not cross. Large buildings will be expanded in the width of the entrance, when used as a ward, the width of the door can be allowed to pass through a mobile bed. 3 beds on both sides of the building, and it also have 2 doors. The multiple units are assembled together in order to adapt to the use of different spatial properties.

As to energy respects (see Fig.7), the air layer formed by the double-layer film can effectively prevent the radiation of sunlight into the room. Thin film PV is used in the outer, which generate electric energy for the building. The light-weight and high-strength light steel material is used as connecting rod structure between two layers of thin films. Frosted film can ensure the privacy of indoor people, and does not influence the daylighting. LED lamp is used as the indoor light source which is more efficient and more environmental than energy-saving lamps. The effect of voltage instability on LED lamp is small. The bottom hole under the structure of the bilayer films, not only play the role of ventilation, while keeping out the sight, and ensure the privacy of the room. The light-weight and high-strength aluminium alloy outer sheath which contains the inner and outer waterproof layer and the middle foam insulation layer, provides a better temperature environment for the people.

Fig. 6: Rainbow Home (provided by the designers)

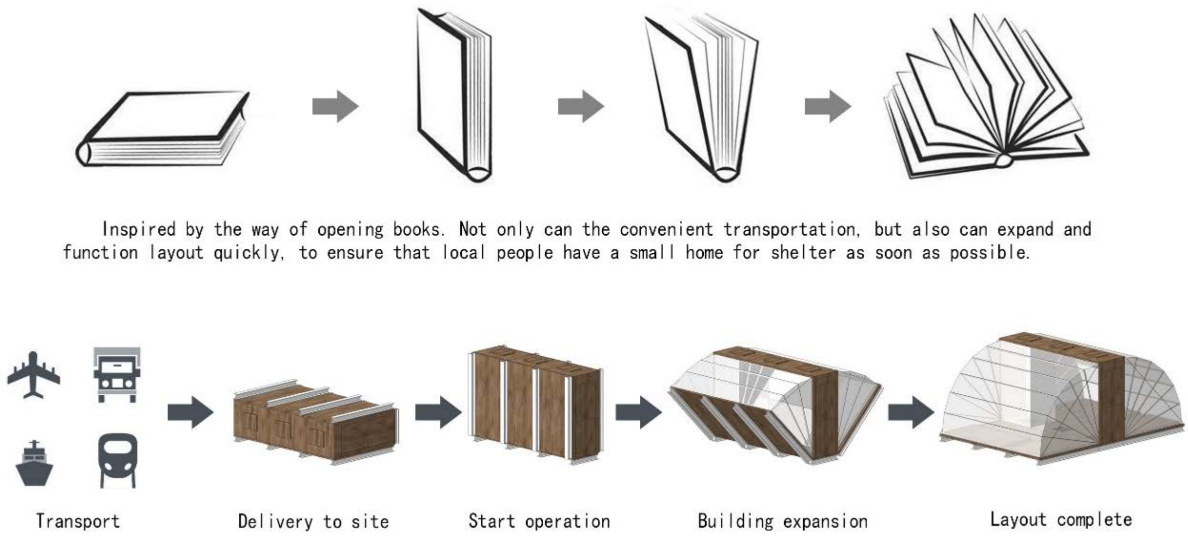
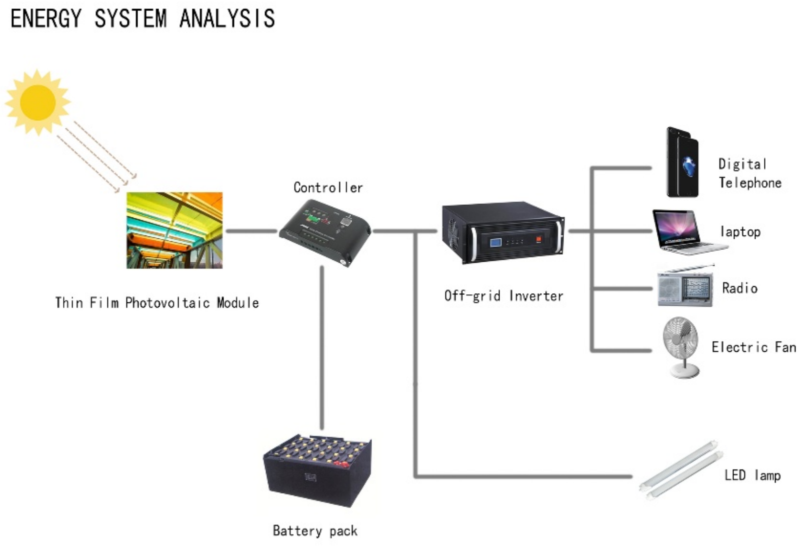


Fig. 7: Construction process of Rainbow Home (provided by the designers)



Selection of off grid photovoltaic power generation system

Equipment	Specification	Quantity
PV lead - acid battery	24V/250Ah	4
PIN/PIN/PIN triple-junction a-SiGe solar cell	50W/1245mm*635mm	10
PV controller	24V/20A	1
PV inverter	24V-220V/2000W	1

Energy consumption analysis of power equipment

Equipment	Power	Time	Number	Power Consumption	Power Consumption
Led lamp	23W	6h/day	2	0.276kwh/day	1.296kwh/day
Electric Fan	50W	3h/day	2	0.30kwh/day	
MT	60W	3h/day	4	0.72kwh/day	

Fig. 8: Energy system of Rainbow Home (provided by the designers)

The Harbour

Through preliminary investigating and analysing, the designers of the Harbour (see Fig.8) think SPESS for Indonesia shelter should meet following several points: 1. the shelter could withstand heavy rain in bad weather and drain off the water as soon as possible, 2. make full use of renewable and sustainable energy such as solar energy to meet the daily energy use after disaster (see Fig.9), 3. collect and purify rainwater for reusing (see Fig.10).

Harbor is a symbol of "home", it can be used as the starting point and the end point. When the typhoon comes, the ship will return to the harbor. It is the place where people take up the courage to move forward again. As the poem described, “Home is a warm harbor, you and I park here, not afraid of rain and wind; Love is a warm harbor, you and I are eager to have it, not afraid of tough journey”. Their design named “Harbor” conveys the secure, warm cultural intention through the expression of architectural form, such as symmetric connection of triangular structure system.

This shelter includes bedroom, living room, kitchen and bathroom in the area of 38.88m^2. In addition, it also has the following advantages:

- Regionality, this design considers the local hot spots to meet the living at the same time and also express the local cultural characteristics by investigating and analysing the local context.

- Adjustable plan, the shelter plan can be changed into four forms according to real needs of disaster affected family. Form 1 could be used to the family with three-generation, or two families of three; Form 2 could meet the family with 6 people; Form 3 could meet two families and each family has three people.
- Adjustable foundation, pile foundations can be adjusted to different height to adapt the complex terrain and this shelter doesn't need special workers to participate the building process.
- Demountable building structure, structural design inspired by the style of Hong Bridge from the famous painting named Riverside Scene at Qing Ming Festival. The structure of the prototype which through short bars connection to meet the large span. Therefore, the connection of the bars can meet the requirements of space and fit the theme.
- Easy to build, in accordance with the building process from bottom to top, from outside to inside. The process of building construction mainly adopts active node design .we can use the rotating shaft to realize the construction of the roof structure, to avoid excessive air task.

Generally, The Harbour is compact and light, its shape is concise and lively, and using a large amount of renewable materials in construction process, while the internal functions can be adjusted to adapted different real needs of disaster affected families. The Harbour also can be converted into community libraries, service stations and other public facilities. Thus, The Harbour is an excellent SPESS designs.

Fig. 9: Architectural expression of Rainbow Home (provided by the designers)

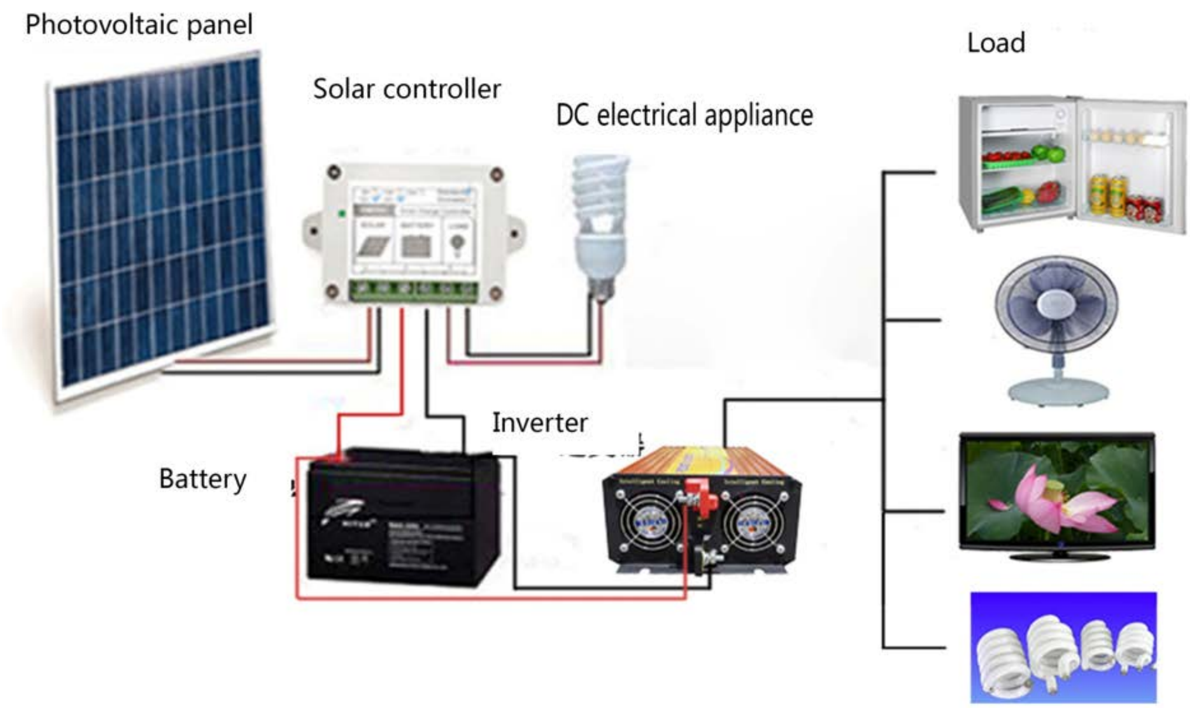


Fig. 10: Energy system of Rainbow Home (provided by the designers)

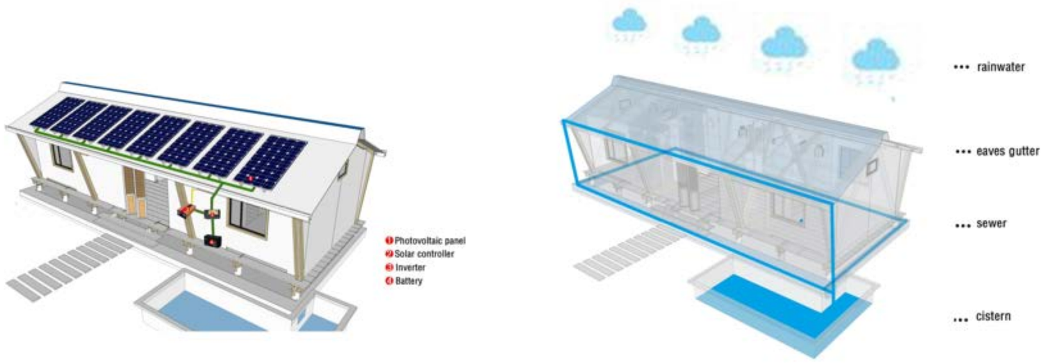


Fig. 11: Rainwater collection diagram of Rainbow Home (provided by the designers)

Conclusion

This Recommendations set out to provide reference information on the potential application of SPESS within the APEC Community through SPESS literature and SPESS open Innovation Competition. Actually, new and renewable energy could play a valuable role in the reduction of emissions but it can also play a greater role in combatting one of the greatest effects of looming climate change in the form of more frequent and violent disasters. The SPESS project can make a difference to people lives and livelihoods by re-establishing communities through the provision of shelter and energy. We can come to the following conclusions from SPESS literature and SPESS open innovation competition above.

- From the SPESS literature, we can conclude that there is an exciting opportunity for the development of integrated solar energy and emergency shelter solutions to assist distressed communities affected by natural disaster. It is of great meaning and necessity for APEC members to apply new energy and renewable energy with local characteristics, such as solar and wind energy, in design and deployment process of emergency shelter as the long-term coping strategy of climate change, especially for the disaster-prone economies.
- From the SPESS open innovation competition, the four SPESS innovation designs submitted by APEC citizens represent a positive and meaningful step towards building sustainable and resilient APEC communities, .Besides, their efforts to promote cooperation and organic combination between energy and humanitarian work are worthy of our praises.
- As the explorer of developing SPESS as an Energy-Resilience Tool for Natural Disaster Relief in APEC Community EWG 22 2015A, APEC Sustainable Energy Center (APSEC) will remain dedicated to advancing further research on this meaningful topic and serving the disaster relief work in APEC region with related stakeholders under the guidance and support of EWG and related working group.
- APSEC always look forward to strength information exchange and achievement sharing with related APEC members and we also expect strong support to push this work to a high level in APEC region in the to be initiated work of SPESS.

End Notes

[1] http://apec2015.ph/apec-2015/, accessed on 3 May 2016.

[2] https://aimp2.apec.org/sites/PDB/Lists/Proposals/DispForm.aspx?ID=1754, accessed on 1 July 2016.

[3] http://publications.apec.org/publication-detail.php?pub_id=1746, accessed on 1 July 2016.

[4] Call for Participants for SPESS Open Innovation Competition (EWG22–2015A)

[5] http://www.apsec.org.cn/apsecen/index.php/Column/?cid=71, accessed on 1 March 2017.