Literature Survey Developing Solar-Powered Emergency Shelter Solutions as an Energy-Resilience Tool for Natural Disaster Relief in APEC Community

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Executive Summary

This literature survey informs APEC forum Energy Working Group (EWG), specifically its sub-forum of Expert Group on New and Renewable Energy Technologies (EGNRET).

Over the period 2005-2014 the Asia-Pacific region had 1,625 reported disaster events. Approximately 500,000 people lost their lives, around 1.4 billion people were affected, and there was $USD523 billion worth of economic damage. In this case the fundamental goal of researching solar and shelter advancements is to save lives and minimise distress for affected communities.

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. One of the key drivers for development of renewable energy research is to drive costs of production lower and gain energy market dominance, reducing emissions and combatting climate change The challenge here is to make solar energy capability advancements applicable to the complex environment of disaster response. While solar energy is again competing with fossil fuel technologies the parameters of the comparison are very different to the traditional technological development criteria. Integrated Emergency Shelter and solar energy must not only be economically viable, but it must be deployable and must not increase the burden of survival on the distressed community.

These case studies inform the understanding of employment of integrated shelter and solar energy in disaster response:

- Philippines 2013 Typhoon Haiyan,
- Employing Solar solutions in Nepal 2015 Earthquake Recovery,
- IKEA Better Shelter, and
- US Military Forces Deployment in Afghanistan.

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 traumatised 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.

12 APEC Economies were assessed for current practice in shelter and solar programs. Potential candidate list for opportunities are presented. This report did not prioritise candidate technology. There are 29 observations which are made through the report and consolidated at the end of the report

This report recommends that SPESS project consider several other issues in the project:

- An Energy Resilient Tool,
- Building Smart and Resilient Cities,
- Understanding Governance,
- Embracing Investment and Partnerships, and
- Enhancing Humanitarian Innovation.

The 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. 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.

The SPESS project can make a difference to people lives and livelihoods by re-establishing communities through the provision of shelter and energy.

Literature Survey
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Project Description and Background

Accounting for 70 percent of all natural disasters, the Asia Pacific is highly prone to climate change impact. One of APEC 2015's priority areas is "*Building Sustainable and Resilient Communities*"[i], and this project aims to foster cooperative efforts to strengthen APEC community's energy-resilience and sustainability affected by natural disasters.

Conventional grid-based energy supply often experiences severe disruptions from natural disasters. Developing Solar-Powered Emergency Shelter Solutions (SPESS) contributes to building an energy-resilient APEC community by providing a secure and sustainable energy supply which is integrated with emergency shelter.

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 Literature Survey Aim and Objectives

This literature survey aims 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).

This literature survey informs APEC forum Energy Working Group (EWG), specifically its sub-forum of Expert Group on New and Renewable Energy Technologies (EGNRET).

Background

Over the period 2005-2014 the Asia-Pacific region had 1,625 reported disaster events. Approximately 500,000 people lost their lives, around 1.4 billion people were affected, and there was $523 billion worth of economic damage. Many of these disasters were on a vast scale, but there were also multiple smaller events that never hit the global headlines. Indeed, since the 1970s, most disasters in Asia and the Pacific have had fewer than 100 fatalities but cumulatively have affected 2.2 billion people and caused over $400 billion worth of damage. Even these figures are probably underestimates, since there is no standardized methodology for gathering disaster statistics, and many disasters go unreported.

The most disaster-prone subregion has been South-East Asia − many of whose countries lie along the earthquake-prone Pacific 'Ring of Fire', or along major typhoon tracks. There are also high seismic and flood risks in South and South-West Asia. The subregion with the greatest economic damage, however, has been East and North-East Asia which has the greatest concentration of exposed economic assets. In the Pacific Island States, the absolute number of people affected may be smaller, but this still represents a substantial proportion of their populations. In general, the most vulnerable countries are those with special needs − including small island developing States, least developed countries and landlocked developing countries.[ii]

Disturbingly, it is warned that the decades ahead will witness increased intensity and frequency of disasters in the Asia Pacific region, exacerbated by climate change and human elements such as unplanned urbanization and poor land-use management.

When natural disasters hit and the conventional grid-based energy supply is severely disrupted, a shelter system with integrated solar energy which is capable of being quickly deployed on-site, is now more achievable than ever. This is not a pioneering science project as the concept that solar power can assist disaster relief has been around for decades. The Florida Solar Energy Centre provided ground breaking insights on 'Photovoltaic Applications in Disaster Relief" in 1995.[iii] However, what was not achievable in 1995 was affordable and integrated implementation of solar energy with shelter systems in disaster relief and recovery.

Renewable energy reduces carbon emissions and provides a means for combatting climate change. Therefore, the drive has been to lower cost per unit of energy to make solar energy economically viable to compete with fossil fuel energy production. While economic value remains a critical objective, the challenge in the SPESS project is to make solar research applicable to the complex environment of disaster response. The key requirement is to deliver an improved integrated shelter and energy system which save lives and improves the rebuilding of communities from natural disaster. This literature review will develop assessment criteria that assist in understanding the requirements for the SPESS project.

SPESS must not increase the burden on the distressed community. It aims to provide 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.

The SPESS project falls under Rank 1 on 2015 APEC Funding Criteria, as it relates to Building Sustainable and Resilient Communities, Emergency Preparedness and Disaster Management, and also Trade & Investment Facilitation and Liberalization. At Boracay in May 2015, APEC officials called for greater commitment and a science-based approach to build safe and disaster resilient communities.[iv] This project can assist EWG in bringing an innovative, low-carbon, energy-resilient technology of SPESS into the mainstream of APEC's science-based Disaster Management framework. SPESS potentially can provide much-needed sheltering and energy for disaster-affected residents, thereby contributing to "build back better" programs earlier and promoting earlier recovery of local economy's trade & Investment activities from the hindrance of natural disasters.

The SPESS project also supports APEC Leaders' Growth Strategy (i.e. Rank 2), as it relates to Sustainable Growth (energy security and energy resiliency including the development of low carbon technology and alternative energy sources), Secure Growth (human security), and Innovative Growth (science and technology approaches in disaster preparedness, risk reduction, response and post-disaster recovery).

Shelter and Energy Use in Disaster Response and Recovery

Disaster Risk Reduction Framework

On 30 September 2015 at the APEC Leaders Forum in Iloilo, Philippines a Disaster Risk Reduction Framework was defined. This Framework provides the approach of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events. It cuts across all areas of the APEC agenda and is described at Figure 1 below:

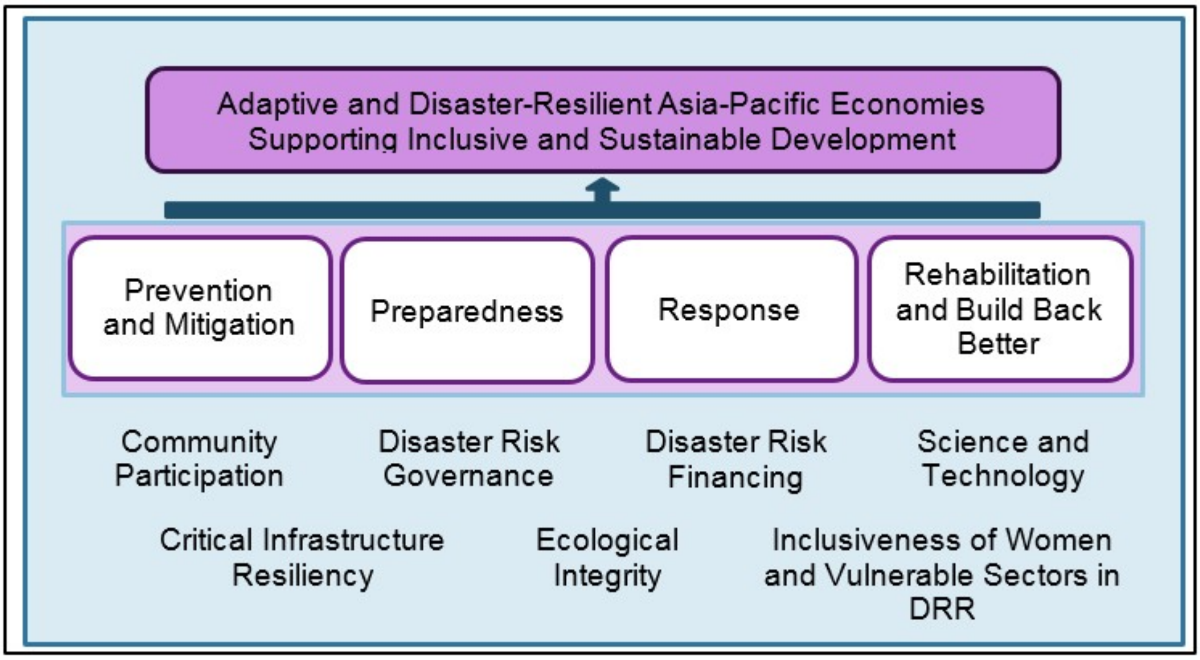

Figure 1: Four Pillars of APEC Disaster Risk Reduction[v]

The disaster recovery and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors is a hugely crowded environment. There are international, regional, sub-regional, national, public and private sector and non-government protagonists competing for space. In addition, there is a plethora of other actors including United Nations agencies, Red Cross and Red Crescent national societies, specialist research centres, development banks, NGO and increasingly, national media that fill every available space to provide niche specialisations or general support to the management of disasters.

This holistic disaster management approach is also based on the idea that there is a responsibility shared by governments, the non-government sector and the private sector as well as disaster management organisations. This idea creates a focus on resilience measures to strengthen communities, individuals, businesses and nations. The private sector, through the APEC Business Advisory Council and local and regional businesses, plays an essential role in this APEC Framework. Sustainable development highly encourages collaboration between the public and the private sectors in recognition of their shared responsibility towards disaster resiliency. As an example, the continuity of businesses largely depends on the efforts of private sector partners. Their continued and sustained contribution toward the development of liveable cities and sustainable communities, resilient supply chains, infrastructure connectivity, and energy will help ensure the success of disaster risk reduction cooperation and its requisite interventions.

> ***Observation 1:*** *The SPESS project has the potential to provide an example of advanced science assisting with direct applications within the complex interconnected international disaster management system.*

Shelters

The United Nations has a cluster approach to strengthen partnerships and ensure more predictability and accountability in international responses to humanitarian emergencies, by clarifying the division of labour among organisations, and better defining their roles and responsibilities within the key sectors of the response.[vi] The natural disaster global cluster lead for shelter is the International Federation Red Cross/Crescent (IFRC).

The Red Cross Movement is involved since decades in providing shelter to the disaster affected. These assistance methods vary greatly depending on the contexts, type of disaster, local capacities, scale and resources. The goal of humanitarian shelter solutions provided in the aftermath of a disaster, are to be life-saving but also to set the path for sustainable reconstruction. The emergency or relief phase, should be instrumental to orient the recovery phase, and integrate risk reduction as a key aspect of reducing housing vulnerabilities – the one housing sector approach. To achieve this, people's needs and preferences are driving the process, as the main objective is to build safer and more resilient communities.

Following a disaster, shelter activities immediately focuses on saving lives. This is particularly urgent where the affected people are exposed to harsh climatic conditions such as extreme cold or heat. Traditional rapid shelter solutions include tents and shelter kits, or materials to build or repair homes. Alternatively, temporary accommodation in public buildings or with host families will be supported.

Shelter assistance needs to be flexible and appropriate to the context, it needs to take the type of damage caused by the disaster into account and consider what is required to complement existing or damaged homes and structures. Successful shelter repair and construction has to go hand in hand with finding solutions for a number of other issues such as electricity, water and sanitation, fuel for cooking and heating, waste management and settlement planning. At the same time public and community infrastructure such as hospitals schools, play areas and health clinics have to be available to affected people.

The ability of vulnerable households to build safer homes can be improved by introducing disaster resistant technologies, raising awareness of the local risks and hazards explaining to vulnerable communities how they can manage these risks better. Post disaster reconstruction activities provide opportunities for men and women to learn new skills related to construction, planning and related issues such as managing natural environmental resources and local project management.[vii]

The IFRC has invested substantial effort in defining standard shelter designs. 10 Shelters Design is a substantial engineering document describing structural shelter design for a variety of conditions. [viii] Surprisingly this technical guide produced in 2013 rarely refers to energy requirements other than as a passing consideration that good shelter systems will be co-located with power, water and suitable sanitation.

In the case of shelter provision in conflict zones and in complex emergencies (natural disaster in conflict zones) the global cluster lead for shelter is shared between the United Nations High Commissioner for Refugees (UNHCR) and IFRC. UNHCR uses two types of tents, depending on needs. One is a lightweight emergency tent that is compact and can be made more quickly than the canvas model. However, its shelf life is less than the canvas tents that UNHCR has manufactured in India and Pakistan. The UNHCR Supply Management Service, based in Budapest ensures that stockpiles of tents are available when the need suddenly appears. The goal is to store tents for 250,000 people - 50,000 tents - at three centres UNHCR has established in Dubai, Copenhagen and Durban, South Africa. UNHCR is also responsible for training personnel, stockpiling shelter and related non-food items and developing emergency shelter strategies, tools and guidelines.[ix]

UNHCR does not restrict its shelter assistance to emergency situations. In more protracted situations, the refugee agency funds rehabilitation of communal shelters or construction of new homes. In some cases, UNHCR provides the uprooted with the materials to build homes themselves under self-help schemes. UNHCR has also established an Innovation Unit to collaborate with UNHCR Divisions, refugees, academia, and the private sector to creatively address complex refugee challenges. Under this program UNHCR in partnership with IKEA has delivered a new shelter system in the Syrian conflict which will be examined in a case study later.[x]

The International Organization for Migration (IOM) has played a major role in humanitarian shelter operations for many decades. IOM's unique position as an intergovernmental organization allows it to work at scale in both natural disasters and conflict/complex contexts. IOM works in both operations and coordination, and plays a strong role working with partners in support of national authorities.

Over the course of 2015, IOM's Shelter and Non-Food Item (NFI) programmes reached over 5.2 million individuals affected by various types of disasters, working in 40 countries overall. IOM Shelter responses are defined following assessments of the needs of affected populations. As a result, following crises, IOM implements a variety of different shelter and NFI programmes operations that cover all response phases in both conflicts and natural disaster affected countries. There is a diverse range of operations and forms of support that take place. Shelter is not limited to construction and distribution. Shelter Activities in 2015 included:

- Stockpiling and preparedness,
- NFI supply chain and logistics,
- Shelter construction, repair and winterization,
- Shelter recovery support and training,
- Rental support through cash,
- Site planning support and upgrade,
- Shelter coordination (IOM leads or co-leads in about 30 percent of responses), and
- Preparedness and Disaster Risk Reduction.[xi]

The Sphere Project – or 'Sphere' – was initiated in 1997 by a group of humanitarian NGOs and the IFRC Movement. Their aim was to improve the quality of their actions during disaster response and to be held accountable for them. Sphere defines acceptable shelter for the affected population as that which provides sufficient thermal comfort, fresh air and protection from the climate to ensure their dignity, health, safety and well-being. The sphere shelter standard describes a number of standard design characteristics and lists successful aspects of past projects.

Sphere defines key indicators for emergency shelter as:

- The design of the shelter and the materials used are familiar where possible and culturally and socially acceptable.
- The repair of existing damaged shelters or the upgrading of initial shelter solutions constructed by the disaster-affected population is prioritised.
- Alternative materials required to provide temporary shelter is durable, practical and acceptable to the affected population.
- The type of construction, materials used and the sizing and positioning of openings provides optimal thermal comfort and ventilation.
- Access to water supply sources and sanitation facilities, and the appropriate provision of rainwater harvesting, water storage, drainage and solid waste management, complement the construction of shelters.
- Vector control measures are incorporated into the design and materials are selected to minimise health hazards.[xii]

Observation 2: *Current emergency shelter design and delivery is a logistics system which is designed to push forward pre-defined and pre-stored solutions. While this approach recognises the need to have well developed solutions there are always better shelter systems coming to market. UNHCR who is responsible for the shelter cluster with the IFRC has recognised the need for humanitarian innovation creating an innovation cell. The shelter standards rarely refer to energy needs other than as a preferable siting need.*

Energy Supply in Disasters

Natural disasters directly threaten energy supply, not only does the functioning of industry, transportation, and communication and computer systems depend on a continuous energy supply, but our complete style of living collapses when energy fails. Furnaces, refrigerators, and other electric appliances don't work. Neither do the electric pumps that deliver our drinking water and help treat sewage. Without electricity for homes, hospitals, food stores, and vital municipal services, many of the most important needs go unmet. On the other hand, electricity power networks have developed to become large and highly complex technical systems, geographically extended, with differing degrees of connectivity, requiring complex operation in real time to balance supply and varying demand.

The complexity of power system networks makes the task of maintaining a highly reliable operation a difficult one, even in normal conditions. Facing short unexpected interruptions has been a challenge for modern power system design and control, and much effort is placed on keeping the system in secure states rather than alert ones. Nevertheless, these efforts occasionally fail, and major blackouts have occurred even as a consequence of isolated faults. Thus, it would be impossible to keep normal interconnected power system operation when major natural disasters occur. Instead, the challenge is to curtail the impact of disasters on the power system and to carry out recovery actions so as to minimize social disruption. That does not divert manufacturers and standards development organizations from designing and building power, communications, and computer equipment that can better cope with the impacts of those disasters in electrical networks.

A reliable electric power supply following disasters is too important to be left to the same old approaches of the past. Historically, emergency response teams have had only one recourse in such a crisis which is to use gasoline or diesel-powered engine generators to provide emergency power. Unfortunately, generators that run on fossil fuels like gasoline and diesel oil have constraints. Foremost the requirement for fuel creates a need for a point of entry (airfield or port) with a supply chain using road transport. All aspects of this supply chain maybe compromised because of the disaster and the need for fuel supplies competes with other resources. The US Federal Emergency Management Agency (FEMA) and other response groups report that generators can also have very short life spans. Many have to be written off the resource list after just one season. Generators are also dangerous in the hands of untrained users.

The World Food Program is responsible for logistics. Strategically located in major transport hubs, Asian regional warehouses aim to ensure that a request for urgent relief items can be met within 24/48 hours. The UN Agencies and NGO operate a network of Humanitarian Response Depots to enhance and coordinate logistics response by jointly storing and delivering their emergency stores including field generators. The IFRC supports the same humanitarian logistic supply chains.[xiii]

The Sphere Project – or 'Sphere' – was initiated in 1997 by a group of humanitarian non-governmental organisations (NGOs) and the International Red Cross and Red Crescent Movement. Striving to support these two core beliefs, the Sphere Project framed a Humanitarian Charter and identified a set of minimum standards in key life-saving sectors which are now reflected in the Handbook's four technical chapters: water supply, sanitation and hygiene promotion; food security and nutrition; shelter, settlement and non-food items; and health action. The Core Standards are process standards and apply to all technical chapters.[xiv] While obviously energy underpins all the technical sections it is underdone as an enabling system. Indeed, there seems to be little scope in the UN standards or ability in the organisational response to define and manage an 'energy budget'.

Understanding the 'energy budget' will help define the characteristics of the energy solution without simply resorting to ad-hoc spot generation while normal grid services are rebuilt. Planning that compliments development of an energy budget will also assist in delivering environmentally and location appropriate energy solutions. Without this understanding of 'energy budget' the SPESS concept will not deliver the best solution. As a Case Study the energy considerations of the response to Typhoon Haiyan will assist in understanding the complexity of the energy budget in disaster response.

Case Study 1: Energy Demand and Response to Typhoon Haiyan Disaster

Typhoon Haiyan caused catastrophic damage throughout much of the Philippine islands of Leyte, where cities and towns were largely destroyed killing at least 6,268 people on November 8, 2013. Restoring electricity to a disaster area is vital for this area to undertake urgent disaster recovery activities. Unfortunately, after every disaster, it usually takes months to bring electric utilities in order so as to bring the grid back to life. During all those months, people of the Philippines were left without access to electricity. To recover from such a disaster, access to electricity source is vital for at least four areas:

Refrigeration: preservation of medicines, vaccines, food;

Water: pumping and making the water drinkable is impossible without electricity;

Telecom, using phone or internet: communication with families, rescue teams, Red Cross;

Light: the day should not be over when the sun goes down.

Electriciens sans Frontières cooperated with other NGOs such as Doctors Without Borders to provide electricity to medical centres and also to makeshift schools. The first team of volunteers installed lighting in the healthcare tents set up around the Guiuan hospital, which was destroyed by the typhoon. They also wired the operating and delivery rooms, and the maternity ward welcomed its first four babies that same evening.

Because of the scale of the destruction, both generator sets and solar-powered lamps were used. UNHCR was able to distribute solar lamps to 6,000 families. The idea behind these solar lanterns is to bring some normalcy to these communities so people are safe for instance it can prevent people from being harassed when they go to toilets. The solar lantern, which provides illumination from six to eight hours, also allows the charging of cell phones – used by affected people.

In contrast to the vulnerability of centralised energy infrastructure, solar photovoltaic panels can make a huge difference to disaster-hit areas. Life for Haiyan survivors was improved by emergency solar power, bringing a continued and affordable source of electricity and making disaster response and co-ordination much easier while centralised power lines are still down. The standalone operations of solar energy systems make them a valuable cost effective resource due to low operating costs and the capability for sustainable solution.

Observation 3: *Beyond the scope of this project but important in setting the correct conditions for SPESS is that currently energy considerations in disaster response rest on traditional spot electricity generation while repairs to existing grid is made. An 'energy budget' strategy will complement and assist SPESS. There is an opportunity to present SPESS as an integrated solution to energy needs*

Solar Energy

Solar power is generated when energy from the sun (sunlight) is converted into electricity or used to heat air, water, or other fluids. There are two main types of solar energy technologies:

- Solar thermal is the conversion of solar radiation into thermal energy (heat). Thermal energy carried by air, water, or other fluid is commonly used directly, for space heating, or to generate electricity using steam and turbines. Solar thermal is commonly used for hot water systems. Solar thermal electricity, also known as concentrating solar power, is typically designed for large scale power generation.

- Solar photovoltaic (PV) converts sunlight directly into electricity using photovoltaic cells. PV systems can be installed on rooftops, integrated into building designs and vehicles, or scaled up to megawatt scale power plants. PV systems can also be used in conjunction with concentrating mirrors or lenses for large scale centralised power.

Solar thermal and PV technology can also be combined into a single system that generates both heat and electricity.

The potential for using solar energy at a given location depends largely on the solar radiation, the proximity to electricity load centers, and the availability of suitable sites. Large scale solar power plants require approximately 2 hectares of land per MW of power. Small scale technologies (solar water heaters, PV modules and small-scale solar concentrators) can be installed on existing structures, such as rooftops. Once a solar project is developed, the energy is captured by heating a fluid or gas or by using photovoltaic cells. This energy can be used directly as hot water supply, converted to electricity, used as process heat, or stored by various means, such as thermal storage, batteries, pumped hydro or synthesized fuels.

There are fixed PV systems and tracking PV systems. Concentrating solar technologies can only focus sunlight coming from one direction, and use tracking mechanisms to align their collectors with the direction of the sun. These systems can be quite complex mechanically and need to be steered to follow the sun, therefore requiring systems that predict the path of the sun and weather conditions such as cloud affecting sunlight. Research continues to advance tracking and steering technologies.

Since 1990, renewable energy sources have grown at an average annual rate of 2.2%. Photovoltaic (PV) energy is one of the most promising emerging technologies. The cost of PV modules has been divided by five in the last six years; the cost of full PV systems has been divided by almost three. The levelised cost of electricity of decentralised solar PV systems is approaching or falling below the variable portion of retail electricity prices that system owners pay in some markets, across residential and commercial segments. For bulk power on grid, PV electricity can already be competitive at times of peak demand, especially in areas where peak electricity is provided by burning oil products. Photovoltaic modules and systems are usually described by their rated capacity, i.e. their output under Standard Test Conditions of 25 ºC, 1.5 Air Mass and 1000 W/m2 of sunlight. This is referred to as the “peak rating” and is written as Watts (peak) or Wp.[xv]

The energy storage industry is evolving rapidly and new technologies could fundamentally shift the way electricity has traditionally been generated and delivered. Energy storage technology has developed tremendously in recent years and is expected to continue to grow. While the costs are still prohibitively high for mass deployment, the trend of reducing costs for battery technologies such as lithium-ion and flow battery technologies suggests that there will be a dramatic shift toward these technologies in the next one to two decades. This will advantage any application of solar technology.

There is an opportunity to make a solar energy applicable to disaster recovery in a method that was envisaged but not possible until solar energy had made the market advances of recent years. However, there are impediments to the application of solar energy solutions in disaster management. In 2015 Nepal suffered from an earthquake causing wide spread destruction. Solar energy has played a role in the energy sector recovery but there are lessons to be learned from poor judgment and misuse of solar energy solutions. These solutions are examined in Case Study 2: How Solar Is Playing a Role in Nepal's Disaster Relief.

Case Study 2: How Solar Is Playing a Role in Nepal's Disaster Relief

On 25 April 2015, 7.8-magnitude earthquake that levelled much of Nepal's capital city of Kathmandu leaving an estimated 1.4 million people in need of immediate help.

With a traumatized population that has dealt with more than 100 aftershocks and new earthquakes, deploying novel technology is a monumental task. While clean energy technologies, especially solar-powered generators, seem like a logical choice during disaster relief efforts, as they do not require fuel supplies to be shipped in. Unlike more traditional technologies such as diesel generators, however, they are often not considered by NGOs during the planning process and are not warehoused and ready to go when emergencies happen.

The cleantech sector needs to work more cohesively with large NGOs and local stakeholders before disasters happen. In some cases, that would involve rethinking how the organizations use power during a crisis, what standard equipment and interconnections look like. Getting shipments through the airport is difficult as the airport is overwhelmed and the government is controlling what can come in and out. Unfortunately, well intentioned solar businesses want to donate units, but this counterproductive to systematic disaster response.

"In order to really make solar energy a viable option it's going to take a determined manufacturer a good amount of time and money to travel, speak to people, do demonstrations, ship units around the country and world, and generate awareness," said Chris Mejia of Consolidated Solar, whose company provided mobile generators to Nepal.

SunFarmer which is a non-profit that installs solar energy in hospitals, health clinics, and schools in the developing world was well positioned to try to coordinate solar assets for the relief effort because it already had staff on the ground that understood local supply chains and stakeholders. "We want to be mindful of not spending money on anything but what's needed," Eller said of SunFarmer's response efforts, even if that was diesel generators. "We're not above that," she said of supporting diesel backup, "but that just wasn't the right technology."

SunFarmer's staff kept hearing that water purification was one of the most pressing needs, so they began looking for solar-powered water purification that could be brought over land from India. When that proved to be too time-consuming, they began assembling their own by connecting purification devices to small plug-and-play systems they already had sourced in-country.[xvi]

The most pervasive use of solar energy was the solar lantern. In Nepal, UNHCR has sent out 8,000 solar lanterns to Kathmandu and surrounding hilly districts. Although solar lanterns are commonly used, "they are profoundly under-valued, specifically for their ability to charge mobile phones to support ongoing communication in areas affected by electrical loss," said Daniel Tomlinson, an access-to-energy entrepreneur and co-founder of Frontier Markets.[xvii]

Many of the hardest hit areas in Nepal did not have reliable electricity before the earthquake, so any solar assets deployed continue to be of value throughout rebuilding. As Nepal cobbles its power system back together in the capital, it has an opportunity to think about the improved resilience that distributed clean energy solutions can provide. Those are questions not just for developing nations, but for every region in the aftermath of a disaster.

Some key assessment criteria for the applicability of solar energy in disaster response can be drawn from Case Studies 1 and 2. These are:

- 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 traumatised 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.

Observation 4: *The key criteria developed for solar in relation to disaster response requirements should guide SPESS assessment of solar technology integrated with emergency shelter design. These are not the considerations for applying solar energy in normal conditions.*

Other Providers of Integrated Emergency Shelter and Energy

General

Advancements in emergency shelter design and integration of energy solutions is taking place away from the direct purvey of emergency shelter in disaster response. This review examines three other influencing domains of integrated shelter and energy design. The first is the construction of refugee shelters by the UNHCR. Secondly is the method by which in military forces are adapting camp and forward operating bases to be more inclusive of innovative self-contained energy solutions. Finally, since many disaster's disadvantage developing economise the most, a link between what is being provided for housing solutions by international development agencies and disaster shelter is important for the SPESS project.

Humanitarian (Refugee Camps)

UNHCR has recognised the need for innovation and implemented a humanitarian innovation program. The IKEA Foundation has been a major supporter of UNHCR for many years. Looking for a dedicated group inside UNHCR with which it could interface and brainstorm new ideas, the Foundation became a founding partner of UNHCR Innovation.

> "UNHCR Innovation is a catalyst in driving out-of-the-box thinking inside the UNHCR organization, and I wanted to be part of that because that's how we think at the company I represent."[xviii]
>
> -Per Heggenes, IKEA Foundation

Case Study 3 examines the IKEA design and implementation of the flat-pack 'Better Shelter', which is a temporary shelter with a lifespan of three years that can be used for disaster victims and refugee camps. It is equipped with a solar light, and it is designed with special attention to transport volume, weight, price, safety, health and comfort. It can be assembled on site without additional tools and equipment.

Case Study 3: IKEA/UNHCR Better Shelter[xix]

The IKEA Foundation partnered with UNHCR and Better Shelter to create safer, more durable shelter for Syrian refugees.

The shelter costs around $1,000 and can house a family of five. Just like an IKEA bedroom set, the entire structure ships in two boxes and takes only four to eight hours to assemble. No additional tools are required.

Not only are the new shelters easy to build, they are safer, more cost effective, and bigger than a typical refugee tent. The 57-square-foot shelter will also last up to three years — compared to the current UN tents' three-month average.

The panels used are lightweight and can withstand rain, wind, and sun. Additionally, the roof is made with a light, reflective fabric that helps reduce the desert heat. The Better Shelter's lightweight yet robust frame is made from strong galvanised steel. It can be anchored to the ground and will withstand rain, snow and strong winds. The roof and walls are made of polyolefin panels treated with UV protection to reduce deterioration caused by strong sunlight. The steel frame is modular, and many of the structure's components are interchangeable. The shelter can easily be dismantled, moved and reassembled. Unlike tents, which may require the entire structure to be changed if any part is damaged, components on Better Shelter units can be replaced individually. The expected lifespan of the structure is three years in moderate climates. The roof and wall panels are made from polymer plastic and can be recycled.

Better Shelter features a solar panel which is installed on the roof, and charges an LED light inside the shelter. When fully charged, this can be used for 4 hours during the nigh time. The light output is between 20-100 lm and the system can charge a mobile phone through a USB port in the lamp.

The rigid frame and panel structure of the shelter reduce the risk of fire related collapse and contributes to the required time for a family to exit the unit. This represents a significant progression in terms of safety in comparison with most non-rigid structure, such as tents. For the intended use, IKEA have together with UNHCR concluded that the shelter's level of fire safety exceeds the fire safety standard for this type of structure.

They also have doors that lock, giving added protection against intruders and sexual assault.

The United Nations has already ordered 10,000 of the units to use in the refugee crisis: 2,600 of the new homes can be found in Iraq, and another 775 across Europe.

Observation 5: *The IKEA 'Better Shelter' is a significant development because it represents a fully designed and implemented integrated solar energy and shelter solution. The nature and type of the solar solution could be improved. SPESS may wish to examine the design and perhaps invite IKEA to be part of the project.*

Military Forces Deployments

The ability for military forces to deploy to austere and threatening environments is an implicit part of military operations. The military forces have made significant advances in deploying smart infrastructure that maximises use of self-sufficient energy. One of the major drivers of moving away from traditional petroleum generators is the need to save lives by reducing the logistic burden and the threat of having supply chains interdicted by enemy forces. Case Study 4 examines the use of solar energy by operational US Armed Forces.

Case Study 4: The Use of Solar Energy by Operational US Armed Forces.

Solar currently provides the military with operational energy that enhances the "tactical edge" and security of deployed US armed forces. In these locations, for these units on the" tactical edge" -- the burden of providing power and energy relies primarily on the force on the ground where the operational costs to deliver power and water are the greatest. Savings will likely be measured in lives rather than gallons of fuel saved.

in June 2011, the Army deployed the 1-megawatt Afghan Microgrid Project (AMP) to Bagram Airfield, and the Marines accelerated deployment of energy-saving technologies to 10 battalions in Afghanistan.[xx] The US military has utilized portable solar arrays to power "fixed-site" locations, many of which are very remote and depend on off-grid power. Solar reduces demand of traditional generators at these discreet locations and in turn, limits the need for costly and dangerous fuel resupply missions that put personnel at risk.

Operational solar also provides these bases with dependable power that is easily portable, compared to obtrusive, heavy, and at times unreliable generators that are often targets for enemy fire. A solar energy system, coupled with battery backup, a diesel generator or thermal energy storage, can operate in island mode. This allows the solar project to continue to provide power independent from the grid, which provides an extra layer of redundancy and reduces the risk posed by blackouts and potential attacks.[xxi]

Other military forces within APEC are examining their need to upgrade their deployable shelter systems. The Canadian Armed forces are examining the procumbent of a deployed shelter system which will consist of up to three sizes of soft-walled tactical shelters capable of flexible configuration, and serving the command post functions of an operations area, a planning area, office and utility areas. Secondary functions such as accommodation may also be supported with this equipment. The shelters will also be capable of connecting to in-service vehicles and vehicle-mounted hard shelters. The system may include tactical lighting equipment; heating, ventilation and air conditioning equipment, and a semi-rigid flooring system.[xxii] Similarly the Australian Defence Force has just commenced examining Deployable Force Infrastructure.

The evolving nature of disaster response means that the interaction between military and non-military actors - the civil-military relationship as it is known, is growing exponentially. This is so globally, but is particularly apparent within the Asia region where military forces are routinely employed as 'first responders' to a disaster. As first responders military forces may provide: direct assistance – face to face with the affected population; indirect assistance – one step removed from the population, for example, transportation of relief goods or personnel; and infrastructure support such as road repair, airspace management or power generation. This means that for emergency shelter and energy solutions that there needs to be some continuity between military and civilian functions.

Observation 6: *Military Operational camps with embedded energy sources such as solar are likely to be world leading in the integrated shelter and energy design. Civil-military engagement is an important element of disaster response in APEC economies and the management of shelter is an important component of civil-military disaster response.*

Linking with International Development Outcomes

International development is a complex arrangement of international agendas, nation state interests, commercial arrangements and host nation needs. As with disaster response there is a plethora of international, regional, sub-regional, national, public and private sector and non-government protagonists competing for space. Many of these organisations directly work across the development and disaster response functions. These crossovers can help with the implementation of 'build back better' strategies after disasters but can also create conflicts of interest and governance challenges.

The UN has set an ambitious agenda for international development in "Transforming our world: the 2030 Agenda for Sustainable Development". In part the vision reads:

> "We envisage a world in which every country enjoys sustained, inclusive and sustainable economic growth and decent work for all. A world in which consumption and production patterns and use of all natural resources – from air to land, from rivers, lakes and aquifers to oceans and seas - are sustainable. One in which democracy, good governance and the rule of law as well as an enabling environment at national and international levels, are essential for sustainable development, including sustained and inclusive economic growth, social development, environmental protection and the eradication of poverty and hunger. One in which development and the application of technology are climate-sensitive, respect biodiversity and are resilient. One in which humanity lives in harmony with nature and in which wildlife and other living species are protected."[xxiii]

Furthermore the 2030 Agenda identifies the Sustainable Development Goals (SDG):

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10. Reduce inequality within and among countries
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts*
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development[xxiv]

The 2015 Sendai Disasters Risk Reduction Framework links these SDGs with disaster risk reduction themes to build a post 2015 development agenda which addresses financing for development and climate change which provides the international community with a unique opportunity to "Build Back Better". Ensuring credible links, as appropriate, between these processes will contribute to building resilience and achieving the global goal of eradicating poverty.[xxv]

International development construction of infrastructure maximises the use of appropriate technology. Appropriate Building Technology is defined as:

- Maximizes the use of locally-available materials.
- Requires locally-available equipment that does not depend on imported supplies of electricity or fuel to operate.
- Draws on skills that are easy to learn and adopt at a community level.
- Are environmental-friendly overall and will not damage the local environment.
- Is used and maintained without external assistance.
- Is safe and affordable.
- Is not necessarily 'low technology' or 'high technology', but provides a capability.
- Skills are easy to learn and adopt at village and community learn.[xxvi]

Developing economies are at higher risk of climate change disasters, according to Verisk Maplecroft's Natural Hazards Risk Atlas.[xxvii] High economic exposure to natural hazards in emerging developing economies are compounded by a lack of resilience factors including economic strength, strong governance, established infrastructures, disaster preparedness, tight building regulations etc., which are much more likely effective and in place in developed economies. Hence, there is a high demand from developing economies for disaster preparedness related projects like SPESS.

> ***Observation 7:*** *This project will need to understand the relative and changing conditions of development identified through the SDGs and Sendai Framework, and in particular the appropriate technologies in place in developing countries. SPESS project will need be specifically tailored to the capacity building needs of APEC's developing economies, featuring strong developing economy involvement in the planning and executing of the project.*

Current Practice in Emergency Shelters and Energy Supply (Assessment by APEC Economy)

Australia

International disaster management is managed through the Australian Government Department of Foreign Affairs. Large scale disasters will often involve a whole of government response with resources from the Australian Defence Force included. Many multinationals and NGOs like World Vision who are part of disaster response have offices in Australia. Domestic disaster response is managed by the States within a federated system which is coordinated by Emergency Management Australia.

Emergency Shelter

Emergency Shelters Australia as part of a worldwide organisation has a "Shelter Box" which is used both internationally and domestically. ShelterBox is a disaster relief tent for a family of up to 10 people. It is custom made for ShelterBox by Vango, one of the world's leading tent manufacturers, and is designed to withstand extreme temperatures, high winds and heavy rainfall. In addition to the tent, there is a range of other survival equipment including thermal blankets and insulated ground sheets, essential in areas where temperatures plummet at nightfall. Where malaria is prevalent mosquito nets are supplied, as well a lifesaving means of water purification. Each box is tailored to a disaster but typically contains a disaster relief tent for a family, thermal blankets and groundsheets, water storage and purification equipment, solar lamps, cooking utensils, a basic tool kit, mosquito nets and children's activity pack. [xxviii]

Deployable Structures International (DSI), a Brisbane based Australian company, produce their fourth generation product FLATTS (FLAT Transportable Structures) RCS (Rapid Construction System). FLATTS RCS is patented worldwide, and manufactured in the first instance by DSI's licensee partners Group Five in South Africa, this building system has been tested at the US Army Proving Ground in Aberdeen Maryland USA, and placed into field trials in the Middle East for energy efficiency trials. FLATTS RCS modules can be assembled in many configurations as a robust and versatile component to help resolve shelter issues.[xxix]

Eden Power market the InterShelter, a patented revolutionary portable shelter, made of a high-tech aerospace composite material, or cutting edge HD plastic that has bridged the gap from tents and trailers to traditionally built framed houses. Built to sustain hurricane strength winds or earthquakes and insulated to stay warm in extreme arctic sub-zero degree weather or cool in hot desert climates, these structures can be assembled in just a few hours by three untrained people. The pieces can fit in the back of a pickup truck, single helicopter sling, or a bush cargo plane and can be set up on almost any terrain. The Dome is a frame-less structure consisting of aerospace composite panels. It has the strength of a standard building but the mobility of a tent. An exterior gel coat which is virtually indestructible covers the panels. This gel coat is resistant to sun, snow, rain or temperatures over 120°F or below 0°F. The gel coat is moulded into the fiberglass giving the Intershelter Dome incredible structural strength.[xxx]

Solar Research

Australian Renewable Energy Agency (ARENA) reports research includes a diverse range of renewable technologies, but there is a clear concentration in solar cells research Solar Cell Technologies with major clusters focused on dye sensitized solar cells, multi-junction photovoltaic cells, quantum dot/crystalline silicon cells and modelling for solar cells. Solar research in Australian universities is performed mostly within Engineering disciplines. [xxxi]

The Commonwealth Scientific Industrial Research Organisation (CSIRO) is committed to making photovoltaic solar cells – a commercialised, readily available solar technology – cheaper, longer lasting and more environmentally sustainable. CSIRO is exploring the benefits of using organic photovoltaics (OPV's) for the production of solar cells include low cost environmentally friendly production methods and light weight flexible substrate that allows a marked change in how and where energy can be generated. Challenges facing developers include how to improve conversion efficiency as currently OPV's are considerably less efficient than silicon cells at converting light to energy. CSIRO are investigating new organic materials (like plastic, which can be printed) and other technologies that will create the next generation of solar cells – they will be lighter, more flexible, attractive and most importantly, cheaper.[xxxii]

The Australian National University has some world leading solar research capabilities particularly with photovoltaics. Of particular note for this study are the light-weight PV programs utilizing thin crystalline Elongate and Sliver solar cells. Monocrystalline silicon is the “gold standard” material for photovoltaics, with proven high efficiency and durability in harsh environmental conditions. Lengthy experience with the manufacture and packaging of silicon solar cells allows manufacturers of commercial modules to offer 25 year guarantees. Thin Elongate and Sliver solar cells offer capabilities combining high cell efficiency (>20%) and durability of monocrystalline Si with the flexibility and low-weight of thin film photovoltaics. The modules contain SLIVER cells, polyester adhesive tape, electrically conductive paste , plated copper busbars, silicone gel encapsulate, and ETFE fluoropolymer sheets to form the outer surfaces of the module. Further, thin silicon cells are lightweight and flexible, and the ability to withstand 100,000 flexing cycles without appreciable degradation has been demonstrated at ANU.[xxxiii]

At The University of New South wales (UNSW) the School of Photovoltaic and Renewable Energy Engineering is internationally recognised for its research in the area of photovoltaics, most of which is conducted under funding from the Australian Research Council and ARENA. The research centres ACAP and AUSIAPV work through SPREE labs. SPREE was also the first organisation internationally to offer undergraduate training in the area of Photovoltaics and Solar Energy, and since then has extended the educational programs offered to include postgraduate and research training opportunities. The Centre holds the world record for the highest energy conversion efficiency for a silicon solar cell at 25.0%. Intellectual property developed by the Centre is being used by the world's largest silicon photovoltaic manufacturing company. Several of the world's largest solar companies were established by or have senior managers (e.g. CTO) who are former researchers or alumni of the Centre of Excellence.[xxxiv]

Observation 8: *Australia has some local emergency shelter design experience, with small innovations but most shelter expertise resides largely in industry and NGOs. Australian government organisations and academic universities do have some world leading solar research capability. There is no evidence of research into integrated emergency shelter and*

Brunei Darussalam

Brunei Darussalam has a National Disaster Council with a subordinate National Disaster Management Centre (NDMC) was set up to manage the impact of a natural disaster. The founding of the NDMC provided Brunei Darussalam with the essential institutional expertise required to coordinate information and assistance in the event of disaster. Apart from that the role of National Disaster Management Centre is to assists and advise the Council in performing its functions. Under the NDMC a team of representatives from relevant ministries were appointed as the focal-point officers in the event of a disaster occurring, these officials will alert the focal point officers for relevant follow-up actions and assign to work 24 hours at the NDMC Centre to respond to any assistance required by victims. It is the responsibility of the NDMC is to alert the public in the event of the scale of disaster occurring in Brunei Darussalam. Overall the NDMC manages, coordinate and mobilize any disaster that happens in Brunei Darussalam.

Brunei Darussalam has a relatively low risk profile for natural disasters.[xxxv]

Emergency Shelter

Brunei Darussalam does not have an indigenous shelter design and construction capacity. There is little evidence of any multinational basing shelter capacity in Brunei. Significantly Brunei has not recently required international assistance in disasters and therefore does not have any locations that have used emergency shelters.

Solar Research

The fast depletion of non-renewable energy resources has been a signicant cause for concern worldwide, especially for an oil-dependent nation such as Brunei Darussalam. In May 2011, Brunei Darussalam's first solar farm, the Tenaga Suria Brunei (TSB), was inaugurated by His Majesty the Sultan and Yang Di-Pertuan of Brunei Darussalam. This farm is the biggest solar demonstration project in Southeast Asia. There is some limited research at the University of Brunei Darussalam.[xxxvi]

> ***Observation 9:** 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 Republic of the Philippines

The Philippines is one of the most hazard prone economies in the APEC region. Its location in the tropics and in the Pacific Ring of Fire exposes it to multiple natural hazards including typhoons, floods, drought, as well as earthquakes and volcanic eruptions. This inherently high disaster risk is exacerbated by the effects of unplanned urbanization, environmental degradation, and global climate change. The resulting human and economic costs of disasters are significant. Over the last ten years, the Philippines have witnessed over 6,000 people killed, over 23 million people affected, and about 1.3 billions of dollars in economic damage.[xxxvii]

The National Disaster Response Plan (NDRP) is the Government of the Philippines "multi-hazard" response plan. Emergency management as defined in the NDRRM Act of 2010 (RA10121), is the organization and management of resources to address all aspects or phases of the emergency, mitigation of, preparedness for, response to and recovery from a disaster or emergency. Local government institutions are responsible for the development and improvement of local response plans relative to their areas of responsibility and underlying risks. The most devastating disasters, depending on capacities may require the full range of government response National/Regional agencies shall respond according to the severity and the magnitude of emergency. INGOs, NGOs, CSOs and private organizations will mobilize their resources and respond quickly.[xxxviii]

Emergency Shelter

Emergency shelter from a wide variety of sources has been employed in the Philippines in the last decade to support a multitude of disaster responses. As described previously in Case Study 1 of the Response to Typhoon Haiyan, most of the emergency shelter is provided by international organisations and therefore is mainly tents. Some innovative steps have been made to take advantage of local Philippine indigenous materials and construction techniques in shelter construction.

After Typhoon Nesat the IFRC in consultation with Philippine authorities constructed 1800 shelters with indigenous planning and design. This shelter was a rectangular structure with a single pitch roof and a covered floor area of approximately 4.8m x 3.7m. The shelter is supported on concrete piers and footings such that the first floor is raised approximately 750mm above grade. The floor and roof are framed with coconut wood beams and joists. The floor is plywood and the roof is corrugated metal roofing. The exterior walls consist of amakan (woven panels of bamboo or palm leaves) fastened to the coconut wood frame. The light weight wood frame can be lifted off the concrete piers and moved to a different location by a small number of people. As designed, the shelter has one door and two windows. Detailed designs of this structure are available through the IFRC shelter design catalogue. [xxxix]

Solar Energy Research

The Philippines Department of Energy (DOE) has moved to promote RE development and use. Solar Philippines, one of the largest developers of rooftop solar power plants in Southeast Asia, has completed its 63.3-megawatt (MW) solar farm in Batangas, providing additional power supply in the western part of the province.

There is some limited research work being undertaken at the Solar Energy cell of the De La Salle University Manilla. The vision is to produce new knowledge through discovery and research on solar energy applications that are relevant and practical in making the society more environmentally sustainable and responsive to the call against environmental degradation. As new knowledge on solar energy applications is produced, it is envisioned that the economy's state of "energy poverty" will be significantly alleviated, most especially in the rural areas. The priority research areas may initially be on materials, devices, processes and systems for photovoltaic electricity generation. Research may also focus on measurements and system characterization as well as studies on performance and reliability improvement of PV components and systems.[xl]

There is some solar research work being undertaken by the Solar Energy Research Institute of Singapore to support the development of solar energy in the Philippines. The Solar Energy Research Institute of Singapore will be discussed under the Singapore Country section.

> ***Observation 10:*** *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

Canada's international disaster response involves the close cooperation among Global Affairs Canada humanitarian officers, Canadian representatives in the field, representatives of other government departments, and international and Canadian humanitarian partners, such as the Office of the United Nations High Commissioner for Refugees, the International Committee of the Red Cross, and the United Nations World Food Programme.[xli] Canada has well established domestic emergency management system which acknowledges an all hazard approach through the Canadian government.

Shelter

Weatherhaven Shelters provides a wide range of deployable shelters in disasters and for military forces. Weatherhaven is headquartered in Canada and has manufacturing facilities is Vancouver, Canada, as well as in South Africa and South America. Combined production facilities cover over half a million square feet (45,000 square metres). Weatherhaven's fabric shelters are the result of 30 years of engineering, designing, and manufacturing tensioned fabric structures. With the standards and footprint of an ISO shipping container and 463L pallet, Weatherhaven's expandable container shelters were built with tactical efficiency and transportability in mind. From concept to deployment, and post-project support, Weatherhaven provides hands-on assistance in all aspects of remote-site logistics including:

- Initial Camp & Shelter Design
- International Transportation & Documentation
- Site Installation
- Dismantling
- Redeployment
- In-Service Support.[xlii]

In the months following the devastating Haiti earthquake in 2010, shelter was one of the most urgent needs for displaced populations. Many found shelter in makeshift camps but further natural disasters such as hurricanes and tropical storms continued to destroy homes and batter Haiti. The Canadian Red Cross Society Transitional Shelter Project, provided medium-term shelter solutions to more than 35,000 Haitians in or around their original places of residence. These shelters were built with consultation with humanitarian experts, architects, and engineers. The result is a safe and dignified shelter, at low-cost, with a high level of adaptability to local needs and conditions.

The shelter is built of wood instead of concrete or bricks, and provide safe, secure and weather-resistant living space. They are modest homes measuring 18 square metres, meant to accommodate five people. To avoid flood damage during the rainy season, the shelters are slightly raised and are engineered to withstand Category 1 hurricane force winds and to be earthquake resistant. Of the more than 7,000 shelters built for the project, none were damaged by the passage of Hurricane Sandy in October 2012.

Since 2010, the Government of Canada, through its Department of Natural Resources, has been exploring ways for the Canadian forest sector to play a more important role in providing shelter solutions for recovery after disasters and civil conflicts. Through a program on expanding market opportunities, the Quebec Wood Export Bureau, a wood industry association, and its members were provided support to bolster their efforts to develop improved housing solutions for people displaced from their homes.[xliii]

A separate innovative shelter design from Canada for the Haiti disaster was a 'Shipping Container Pop-Up Village for Haiti'. Shipping containers sit in port cities around the world, empty and unneeded. Designed by Montreal organization Vilaj Vilaj, the community of 900 shipping containers housed 5,000 people and would provide open spaces, parks, and playing fields. Each 320-square-foot shipping container home would come complete with running water and bathroom facilities.[xliv]

There are several small to medium enterprises located in Canada design and delivering emergency shelter. One of these is Deployable Structures Inc which design and manufacture fully articulated aluminium framed, vinyl coated polyester soft walled portable shelter systems with optional cold and tropical weather insulation kits. Complete standalone HVAC and air purification systems are offered for remote camp locations. The Habitat and Long Habitat series of shelters require no tools for setup. All shelters are free standing with full 185 cm vertical sidewalls and come with an array of supporting accessories like shelter interconnection kits, custom fit vinyl ground covers, portable bunks, table/desk sets with shelves, integral light and wiring harness sets.[xlv]

Solar

Natural Resources Canada is responsible for Canadian Government solar energy activities. In Canada, Photovoltaic (PV) technology has become a favoured form of renewable energy technology due to a number of social and economic factors. The primary mandate is to help develop and deploy photovoltaic energy technologies in Canada. To this end, two strategic approaches are being taken. The 1st is to accelerate the deployment of solar power in Canada, while the 2nd aims at exploiting solar energy's potential, both nationally and internationally.

Researchers at Canmet Energy collaborated with the Xeni Gwet'in First Nation in British Columbia's Nemiah Valley to test the viability of a hybrid photovoltaic-diesel mini-grid to help reduce the community's electricity costs. To achieve this, the partners first studied ways to improve the efficiency of the current genset and then installed a system of photovoltaic (PV) solar panels. The Nemiah Valley genset initially consisted of three 95-kW diesel generators, which supplied 22 homes and a commercial zone. However, like in most remote communities, the generators were oversized in comparison to the relatively low energy demands, leading to significant efficiency losses.

To avoid this loss of energy and the associated overconsumption of fuel, researchers at CanmetENERGY recommended replacing one of the three diesel generators with a smaller one. The new 30-kW generator now takes over at night and on weekends, eliminating non-critical loads in the commercial zone. After solving this deficiency issue in the existing diesel mini-grid, CanmetENERGY and the Xeni Gwet'in Nation added PV solar panels to help lower the community's electricity costs and provide researchers with the opportunity to design and study a hybrid system for the first time. The 27.36 kW of PV installed represent approximately 36% of the grid's peak load, and supplies 11% of the users' yearly electricity needs.[xlvi]

The Institute for Sustainable Energy (ISE) at the University of Toronto is an inclusive, multidisciplinary centre designed to bring together researchers, students, and teachers from across the university, together with partners from industry and government, with the goal of increasing energy efficiency and reducing the environmental impact of energy use and conversion. One program is examining new materials — organic solar cells and quantum dots — that can increase the efficiency of solar power while reducing cost. A team has designed the most efficient catalyst for storing energy in chemical form. This new catalyst facilitates the oxygen-evolution portion of the chemical reaction, making the conversion from H2O into O2 and H2 more energy-efficient than ever before. The intrinsic efficiency of the new catalyst material is over three times more efficient than the best state-of-the-art catalyst. The new catalyst is made of abundant and low-cost metals tungsten, iron and cobalt, which are much less expensive than state-of-the-art catalysts based on precious metals. It showed no signs of degradation over more than 500 hours of continuous activity, unlike other efficient but short-lived catalysts. The Institute is working with major engineering firms like H.H. Angus & Associates Ltd. and Hatch, as well as energy companies such as Constant Power.[xlvii]

Canadian Solar operates as a global energy provider with successful business subsidiaries in 20 countries on 6 continents. Besides serving as a leading manufacturer of solar PV modules and provider of solar energy solutions, Canadian Solar has a geographically diversified pipeline of utility-scale power projects.

> ***Observation 11:*** *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

While Hong Kong, China has been relatively free of natural disasters like earthquakes and tsunamis, there is still a need for the city to strengthen its preparedness and capabilities for handling a disaster or major emergency. Led by the Hong Kong Academy of Medicine (HKAM) in collaboration with the medical schools of The University of Hong Kong (HKU) and The Chinese University of Hong Kong (CUHK), and supported by international experts from the universities of Oxford and Harvard, the Hong Kong Jockey Club Disaster Preparedness and Response Institute (DPRI) was established in 2014

The HKJC DPRI aims to consolidate and institutionalise the current capabilities of disaster preparedness and response in Hong Kong, China, with the ultimate goal of developing a sustained local, national, and regional centre of excellence in this field. The Institute concentrates on medical response and preparedness.[xlviii]

Emergency Shelter

Emergency Shelter Design in Hong Kong is focussed on the very real need of managing a substantial need within the confines of Hong Kong. However, some of this work and knowledge is transferable to the international disaster response. Working with Hong Kong architecture studio AONA and charity One Village Focus Fund, the Hong Kong architects have built their first prototype in the village of Duwakot in Nepal following the 2015 earthquake. Measuring three metres wide and six metres deep, the building is clad with timber and metal sheets sourced from wrecked houses. It was built in two days by a team of four paid workers and 10 volunteers. The same triangular-frame structure could also be used to build nurseries, clinics, community centre or schools, said the team – as will be illustrated in the downloadable assembly guides.[xlix]

Solar Research

Researchers at The Hong Kong Polytechnic University are designing efficient solar cells. These hybrid solar cells can convert up to 25.5 per cent of solar energy. The solar cells could also be used on "wearable" technology and consumer electronics due to the material's flexible nature, and not just on solar panels outside buildings and on rooftops. The research team works with the university's Institute of Textiles and Clothing to create a transparent top coat with a texture similar to that of rose petals to help trap more light.[l]

The Hong Kong University is strategically focused on health research but there is some selected research being done on solar PV and storage systems.[li]

> ***Observation 12:*** *Hong Kong, China has the Asia Disaster Preparedness Institute which is focussed 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

With its vast territory and diverse climatic and geological conditions, China is subject to a wide range of natural and man-made disasters. The operational mechanism of disaster management system in China can be summarized as: unified leadership, graded response and functional division, based on local government, supplemented by central government. Unified leadership means the government issues policies, regulations and planning, and makes decision, commands, supervises and coordinates in the course of implementing disaster management measures. Graded response means central government is responsible for management of catastrophe relief, and local government for disaster management in their administrative areas. For example, the central government takes responsibility for major disasters, provincial government for large-scale, municipal government for medium-scale, and county government for minor disasters. Functional division is that relevant departments of the government shall be responsible for relevant work of disaster management in accordance with their respective duties. The practice and expenditure mainly depend on local government and supplemented by central government.[lii]

China is increasingly playing a leadership role in international response and making the immense domestic disaster response capacity available as part of humanitarian action. There is a strong desire to improve the planning and implementation of assistance to make it more efficient and effective. This includes engaging more directly with affected governments to assess needs, improving coordination among China's agencies, and increasing coordination with donors and international agencies. Organisations like the Chinese Red Cross and China Foundation for Poverty Alleviation have extensive experience working in China and are now expanding their activities internationally.

For the SPESS project it is important to note the primary role of Tianjin University as the key promoter, the APEC Sustainable Energy Centre. The centre is a mechanism and platform for sustainable energy development in the Asia-Pacific region, APSEC will enhance information sharing, policy exchange, joint research, demonstrations and promotion, and capacity development among APEC economies, spreading advanced ideas and mode of sustainable development throughout the region.

Emergency Shelter

China has tremendous capacity to produce shelters. Mege Shelters was stablished in 2000, and is located in,Guangzhou City. Mege owns independent technology of composite materials, staff with many years' experience in practical projects and complete production facilities and is a market leader in shelters, container houses, special truck bodies, recreational vehicles, and modular houses. In a similar method to Canadian works in Haiti, Mege was responsible for the Re:START village project in Christchurch New Zealand in 2011. The recycled shipping containers served as a fast yet crucial solution in the process of urban renovation. The development took only a couple of months to construct a comfortable public and social areas capable of sheltering local stores that were destroyed in the earthquake, making a unique shopping mall made out of shipping containers.[liii]

Mege is able to produce a fibreglass replacement panel structure, with a welded steel framework, and integrated solar panel, good water-proofing performance, durability and easy maintenance. The shelter is convenient to transport has good thermal insulation, corrosion resistance and anti-aging.[liv]

Nanjing Sanchuan Pavilion Mfty. Co. Ltd is a large professional tent manufacturer for emergency shelter and military tents. Currently Nanjing Sanchuan Pavilion Mfty. Co. Ltd produce emergency shelter for refugees, refugee tents, military tents, administration shelters, wedding tents, garden pavilions, carport and Mongolian round tents (Yurts). All designs are made of sturdy frames and resistant, durable fabrics. The UNHCR utilises the tents which are produced to meet international and UN approved standards at low pricing. All tent shelters are simple to erect and very durable, even in heavy weather conditions with a usable floor area between $12m^2$ and $16 m^2$, depending on needs. Winter tent kits and winter tents for housing refugees and disaster victims in colder climates are available and large qualities of tents are available for immediate shipment if required. [lv]

China is also able to offer innovations outside large production businesses such as the 'Folding Bamboo Houses' by Ming Ting. The concept utilises a system of bamboo poles that are pre-assembled into rigid geometric shapes. The geometry of these forms provides each structure's integrity, allowing a range of lightweight modular structures to be quickly assembled in factories and transported to their destination. Once constructed, the shelters are then covered by using post and pre-consumer recycled paper. The Flexible structure is designed to resist earthquake, easily produced, cheap and environmentally friendly. The geometric folding houses are architecturally appealing, dynamic, and can adapt to respond to the needs of different situations.[lvi]

Solar Research

China has long been the world's largest manufacturer of solar panels. Trina Solar was founded in 1997, and listed on the New York Stock Exchange since 2006. Trina Solar specializes in the manufacture of crystalline silicon photovoltaic modules and system integration. Today Trina Solar is the world's number 1 solar PV module brand with a total shipment volume in 2014 of 3.66 GW. Trina Solar is not only a pioneer of China's PV industry, but has become an influential shaper of the global solar industry and a leader in solar modules, solutions and services.

Trina Solar has partnered with many of the world's leading PV research institutes to advance solar technology. Three of these initiatives are:

- Solar Energy Research Institute of Singapore: Co-development of a back contact cell. Targeting 21.5% production efficiency, and up to 23.5% laboratory test efficiency within 3 years
- Australia National University: A 24.4% maximum conversion efficiency has been achieved in the lab for n-type mono c-Si cells. Small-scale pilot production can currently reach a

- maximum conversion efficiency of 21%, and the corresponding mass production line is already in production.
- Universidad Politécnica de Valencia: Guest lectureship of PV specialization training program; Cooperation on doctorate-level photovoltaics research.[lvii]

Suntech develops, manufactures, and delivers the world's most reliable and cost-effective solar energy solutions. Founded in 2001, Suntech have supplied more than 10 GW photovoltaic panels to more than a thousand customers in more than 80 countries.[lviii]

China National Renewable Energy Centre (CNREC) is the national institution for assisting China's energy authorities in renewable energy policy research, and industrial management and coordination. CNREC's establishment is an important part of the Sino-Danish Renewable Energy Development Programme, a joint effort between China and Denmark which aims a developing the renewable energy technology and the capability of the authorities to manage the rapid development for renewable energy in China.[lix] The CNREC 2050 Roadmap predicts there will be active technological research and development in the area of solar cells. The main future development direction is still high efficiency and low cost. The cost of PV generation will keep the trend of decrease, and realize price parity in China by 2025. The mid- cell commercialization module efficiency of crystalline silicon will be over 20%, and dominate the market in near and mid-term. By 2030 thin-film technology will breakthrough and efficiencies will be approaching crystalline silicon, the market also get 50% share with crystalline silicon cells. By 2025, solar PV will achieve grid parity. After 2030, solar PV will become one of the main replaced power source; after 2050, solar PV will become one of the leading power sources.[lx]

Observation 13: *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

As it is situated along the circum-Pacific volcanic belt, Japan has several volcanic regions and frequently affected by earthquakes and Tsunami. The Disaster Management Plan is the master plan and a basis for disaster reduction activities in Japan, and is a plan made by each designated government organization and designated public corporation. The plan clarifies the duties assigned to the Government, public corporations and the local government in implementing measures. For easy reference to countermeasures, the plan also describes the sequence of disaster countermeasures such as preparation, emergency response, recovery and reconstruction according to the type of disaster. In prefectures and local municipalities, the prefectural and municipal Disaster

Management Councils are established with the members of representatives of local government organizations including police and fire management department, and designated local public corporations. [lxi]

Toward reconstruction from the Great East Japan Earthquake, the Government of Japan sets it as our foreign policy to make consistent contribution in humanitarian assistance. It is one way to acknowledge solidarity expressed by the international community after the Great East Japan Earthquake. From these standpoints, the Ministry of Foreign Affairs formed basic concepts of humanitarian assistance of our country as "Humanitarian Aid Policy of Japan". The Government of Japan has three tools for emergency assistance for overseas disasters: Dispatch of Japan Disaster Relief Team; Provision of Emergency Relief Goods; and Emergency Grant Aid. [lxii]

Emergency Shelter

Japan has constructed established permanent emergency shelters across Japan to come with the imminent threat of disaster in Japan. There is also a thriving market for delivery of transportable temporary emergency shelters. Daiwa Lease has an extensive track record in both permanent and temporary emergency shelter production. They provide design based on customer needs and speedy construction of buildings that present prefabrication in an entirely new image, covering everything from the construction of temporary structures to public facilities such as hospitals and schools.[lxiii]

The EDV-01 Emergency Shelter is a high-tech shelter from Diawa Lease and is about the size of a shipping container, though it can double in height with a flick of a switch. It can sustain itself without any outside resources for up to a month by catching and reusing water, and generating electricity with a sizable solar array. The EDV-01 can be transported by truck or helicopter to areas in need. Bunk beds and an office desk are built in. The lower portion has a shower and a bio toilet, a small kitchen, storage for supplies, and equipment. A unique aspect of this shelter is its pixelated skin that can light up and serve as signage, providing critical emergency information to people in the community.[lxiv]

Innovative shelter is a strong characteristic of Japan's emergency shelter industry. Shigeru Ban Architects are a world leading innovator of emergency shelters. Architect Shigeru Ban has proven that paper tubes are a strong, durable, cheap and simple way to build emergency shelters. Ban's disaster housing has been used everywhere from Rwanda to Kobe, Japan. Ban also recognised that while evacuation centers were providing a safe refuge to Japanese citizens, they would also become crowded with little provision for privacy. In response, he devised a curtained partition system that could provide some relief to the individuals – an important point, as they will likely have to wait months before the government-built relief homes are completed.[lxv]

Solar Research

Japan was the first economy to aggressively support development, manufacture and use of PV but there were entrenched energy politics which curtailed the initial drive of solar. Since the Japanese earthquake and tsunami in 2011, the economy has understandably seen an explosion of interest in renewable energy. A plethora of wind and solar projects were announced, especially in the early days after the Fukushima nuclear plants were shut down. Goldman Sachs said recently that it will invest as much as $487 million in Japanese fuel cell, solar, wind and biomass efforts. The Japanese government, meanwhile, has set renewable targets of between 25% and 35% of total power generation by 2030, by which time some $700 billion would be invested in new, renewable energy.

J-space systems has been studying Space Solar Power System (SSPS) as an alternative future energy resource under a support of METI (The Ministry of Economy, Trade and Industry) and the other related agency for the past several years.

The Osaka University Research Centre for Solar Energy Chemistry is examining:

- Solar Energy Conversion,
- Photovoltaic and Photocatalytic Materials
- Environmental Photochemical Engineering
- Nanophotochemistry.

> ***Observation 14:*** *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.*

Republic of Korea

The National Emergency Management Agency (NEMA) established under the umbrella of the Ministry of Public Administration and Security (MOPAS) is comprehensively in charge of disaster management policies in Korea. The National Disaster Management Institute (NDMI) established in 2006 prepares and trains for national and international disasters. The National Disaster Management System (NDMI) includes disaster management support systems that are installed in the central and local governments to take action against both natural and human-made disasters. The NDMS is jointly operated by the national government, local governments, and related authorities. It is a nationwide information system to prevent dangerous factors that can threaten human lives and properties, to promptly respond to emergency situations, and to support recovery and restoration. The local systems are for users in the local governments in 231 cities and provinces nationwide. [lxvi]

Emergency Shelter

Korea has a large network of permanent emergency shelters in preparation for potential conflict. There is some well-developed temporary shelter design and production in Korea. 'Love Homes' are built for neighbours who have lost their homes. Over 300 homes are completely destroyed every year due to natural disasters. Hope Bridge provides temporary residential facilities to help support those in difficulty. The temporary residences are assembly-type homes that are 6m x 3m (about 16m2) and can be moved and installed conveniently. Each residence is equipped with electric and communication facilities, bathrooms, sinks, boilers and fire extinguishers so that two to three adults can live in it comfortably. The temporary residences are built with high quality materials that have passed inspections by official testing institutes, and can be used in both the summer and winter seasons.[lxvii]

Solar Research

The Korean Institute of Energy has well developed plans for future technology development of solar energy. Like many APEC economies it is implementing the strategic development of technology that can reduce the manufacturing costs of crystalline silicon and next-generation thin film solar cell that which will also reduce the manufacturing costs of the solar cell.[lxviii]

SunPower, a U.S. solar panel maker and power project developer, has a joint venture in Korea called Woongjin Energy Co., which makes silicon ingots for manufacturing solar cells. SunPower announced the partnership with Woongjin Holdings Co. back in November 2007, and said at the time that it was going to spend $250 million buying the ingots from the joint venture over a five-year period.[lxix]

Korea has a strong home-grown solar energy industry. The economy is home to some of the world's largest makers of flat display panels, whose manufacturing processes are similar to making solar panels. Last October, LG Electronics said it was converting one of its plasma production lines in Korea to make solar cells. In 2008, Hyundai Heavy Industries built its solar cell factory, which has an annual production capacity of roughly 30 megawatts. Hyundai has a $40 million deal to sell modules to MHH Solartechnik in Germany starting this year. [lxx] Other Korean solar energy equipment companies include DC Chemical, Smart Applications, Nexolon, Kyungdong Photovoltaic Energy and NeosemiTech, according to a recent Greentech Media solar market report, PV Technology, Production and Cost, 2009 Forecast.

Observation 15: *Korea emergency shelter has been focussed 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 Republic of Korea.*

New Zealand

New Zealand's greatest natural disaster risk comes in the form of earthquakes, due to its location in an area of seismic shift. A devastating 6.3-magnitude earthquake struck Christchurch on the South Island in late February 2011, killing more than 180 people and resulting in severe structural damage. Thousands of aftershocks have been recorded since then, including one which was as big as the original quake and brought down more buildings. New Zealand has The National Crisis Management Centre (NCMC) which facilitates the Central Government crisis management arrangements and offers inter-agency and scalable operability to deal with any type of emergency. The NCMC is managed and maintained in a continued state of readiness by the Ministry of Civil Defence & Emergency Management (MCDEM).[lxxi]

The Pacific is the core focus of New Zealand humanitarian and disaster management efforts. New Zealand shares close cultural, political and social links with the Pacific and are a trusted partner that can respond quickly in support of Pacific governments when a disaster strikes. Pacific island countries are among the most vulnerable in the world. They are particularly susceptible to cyclones, floods, droughts, volcanic activity, earthquakes and tsunami. The impacts of climate change and unpredictable weather patterns are exacerbating disaster risk. Small island developing states in the Pacific also face disproportionally high risks to extensive loss and damage due to their small and vulnerable economies. The impact of multiple disaster events can have devastating consequences on the lives of people and their communities, as well as on entire economies for many years. Providing technical expertise from New Zealand helps re-establish essential infrastructure such as telecommunications, airports and power services for example – often in partnership with the private sector.

Emergency Shelter

New Zealand does not have a significant shelter design and construction capacity. There is little evidence of any multinational basing shelter capacity in New Zealand. Emergency Shelters New Zealand like Australia is part of a worldwide organisation has a "Shelter Box" which is used both internationally and domestically.[lxxii]

Solar Research

The New Zealand market for photovoltaic systems is relatively competitive. Generally, in the past PV module supply in New Zealand has been through a local wholesaler who purchases from an Australasian distributor. There are now a number of local distributors purchasing direct from overseas manufacturers, resulting in more competitive PV module prices.

Further opportunity exists with the development of new PV cell materials, including work at Massey, Otago, Canterbury Universities and Industrial Research Limited (IRL). While there is presently no PV cell or module manufacturing in New Zealand, local organisations are beginning to embrace the technology, incorporating PV technology into building products such as the commercially available "Solar Rib" product produced by Calder Stewart.[lxxiii]

At the University of Waikato, the Solar Energy Research Group (SERG) has expertise in solar thermal, photovoltaic and optical modelling, specialising in building integrated systems. SERG has the only photovoltaic laminator in New Zealand and test facilities for both photovoltaic and solar thermal systems.[lxxiv]

The University of Auckland is examining smart grid infrastructure that increases competition among suppliers by enabling advanced automation, integration of a high level of distributed resources, and the intelligent end-use technologies resulting in increased value and improved reliability.[lxxv]

> ***Observation 16:*** *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

The Singaporean Ministry of Home Affairs is the principle policy and directing authority responsible for civil defence emergency preparedness and disaster management. Under its command are two emergency agencies - the Singapore Civil Defence Force (SCDF) and the Singapore Police Force which are responsible for planning, co-ordination and implementation of the various programmes and activities. To fulfil its roles, the SCDF has established 4 systems to cater to Singapore's emergency needs - Warning; Protection; Rescue; Command, Control and Communications.

The SCDF maintains a dedicated 76-man standby contingent round-the-clock codenamed Operation Lionheart where its core function is to provide urban search and rescue and/or humanitarian relief assistance to countries afflicted by major disasters. The Operation Lionheart contingent comprises rescuers from the SCDF's elite Disaster Assistance & Rescue Team (DART) and from the frontline units including Operationally Ready National Service (ORNS) men.[lxxvi]

Emergency Shelter

Singapore does not have a large shelter production facility but has innovative niches. An example of this innovative niche is the Adaptable Metaplate Disaster Shelter by Singapore designer Kelvin Yong. The 'Metaplate' disaster shelter is made from durable but inexpensive materials like cardboard impregnated with resin and can accommodate piping, drainage and other necessary domestic facilities. The prefab housing simply folds up into a rectangular structure, making it very easy to transport and assemble.[lxxvii]

Solar Research

The Singapore Solar Energy Research Institute is internationally renowned and involved in many partnerships across the Asia Pacific. The Solar Energy System Cluster aims at making solar power a cost-effective and trusted source of electricity in Asia by:

- increasing the availability through designing high-performing solar systems (locations, components, layout, applications)
- increasing the reliability through close monitoring and remote controlling of solar power systems; and
- increasing the predictability of PV electricity generation through forecasting of solar irradiance

This R&D cluster comprises five groups:

- Novel PV Concepts,
- Silicon Materials and Cells,
- PV Modules,
- Solar Energy Systems, and
- Solar and Energy Efficient Buildings.[lxxviii]

> ***Observation 17:*** *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

Located on the East side of Asia, Chinese Taipei is an island with significant risks for natural disasters. The 2011 Disaster Prevention and Response Plan is a comprehensive plan for dealing with the different nature of disasters.

Shelter

There is limited evidence of emergency shelter production or innovative design in /Chinese Taipei.

Solar

The Chinese Taipei Industrial Technology Research Institute (ITRI) is a non-profit R&D organization engaging in applied research and technical services, aiming to innovate a better future.
Over the years, ITRI has nurtured more than 240 companies, including well-known global semiconductor leaders such as TSMC and UMC. ITRI continues to seek strategic collaborative partners from around the world. Key partners include Corning Glass, Underwriters Laboratories, and Applied Materials of the United States; Asahi Kasei, Nidec, and AIST of Japan; Evonik, Heraeus, and Fraunhofer of Germany; TNO of the Netherlands; VTT of Finland; Ericsson of Sweden; and NRC of Canada.

It is a world leading solar research facility. One of the key areas of research is the ultrafast rechargeable aluminium-ion battery is made of an aluminium anode and a graphite cathode. Researchers from ITRI and Stanford University used the layered structure of graphite to allow chloroaluminate anions to perform the intercalation and deintercalation reactions. [lxxix]

> ***Observation 18:*** *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*

The United States

The initial First Response to a disaster is the job of local government's emergency services with help from nearby municipalities, the state and volunteer agencies. In a catastrophic disaster if the governor requests, federal resources can be mobilized through the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) for search and rescue, electrical power, food, water, shelter and other basic human needs.[lxxx]

The Office of U.S. Foreign Disaster Assistance (OFDA) is responsible for leading and coordinating the U.S. government's response to disasters overseas. OFDA responds to an average of 65 disasters in more than 50 countries every year to ensure aid reaches people affected by rapid on-set disasters—such as earthquakes, volcanoes, and floods—and slow-onset crises, including drought and conflict. OFDA fulfils its mandate of saving lives, alleviating human suffering, and reducing the social and economic impact of disasters worldwide in partnership with USAID functional and regional bureaus and other U.S. Government agencies.[lxxxi]

There are many NGOs that work from the United States. For example, the Harvard Humanitarian Academy which is dedicated to educating and training current and future generations of humanitarian leaders. The academy aims to create a professional pathway for students and practitioners of all levels in the humanitarian space and to serve as a prototype for other academic centres of excellence in humanitarian education.

Emergency Shelter

The United States has a very comprehensive shelter design and production capability. There is a significant domestic market that deals with storms and tornadoes each year. For example, Sprung Structures provides Government agencies, non-profit and non-governmental agencies, and disaster relief organizations with instant building solutions. A Sprung structure is ideal for disaster recovery operations that require immediately deployable buildings for temporary emergency applications. Available as semi-permanent alternatives to conventional construction, sprung structures are flexibly designed to be constructed and built quickly and effectively to help you save time, money and even lives. With limited need for foundations and attractive energy-efficient insulation packages available, sprung structures are also easily dismantled and relocated for any future disaster recovery needs.[lxxxii]

There are many innovative emergency shelter designs in the US. These range from implemented to concepts only. The Mastodon 'Transient Response System' is a concept only and is designed by, from SCI-Arc in Los Angeles. It is a mobile skyscraper which has a deployable architectural base (called the MASTODON) that self-assembles using four giant jacks into a shelter for earthquake, flood and other natural disaster victims. The tower will be equipped with solar panels, wind turbines and a rainwater catchment system to generate power and provide water for its temporary residents.[lxxxiii]

The New York–based architectural firm Gans and Jelacic has developed disaster-relief housing that is more than temporary shelter, which was deployed in Bosnia/Kosovo conflicts. The structures also attempt to accommodate the long-term hopes and dreams of displaced people. It starts out as a small triangle, but unfolds into a four-by-eight-foot room that can not only withstand years of use, but can be used as a basis for more permanent housing. Architects Deborah Gans and Matthew Jelacic created this compact concept for the Architecture for Humanity competition after studying both immediate and long-term disaster housing and realizing that permanent homes are often constructed around emergency settlements. The unit, made of scaffolding, is easy even for elderly people to assemble and the beams are strong enough to be used as structural support in long-term construction.[lxxxiv]

Nader Khalili has designed the Sandbag/Superadobe/ Superblock Construction System. This simple emergency and safe structures gives maximum safety with minimum environmental impact, using natural materials Emergency Shelters. This type of emergency shelter was used as a response to the 2005 earthquake in Pakistan. The challenge was to provide quick, safe, decent shelter with minimal tools and supplies to sustain life through the winter. It could provide more permanent shelter with modest modifications. The First Aid Earthquake House is made out of very simple materials: sand bags, rope lines, tape and available insulation materials. The construction process begins with filling the sand bags with fine and heavy materials, where this is possible. The house is designed in such a way that people can construct this facility themselves.[lxxxv]

Solar

The US has been actively involved in PV research for many decades, its market was relatively slow to develop overall, but is now a world leader in solar application with increasing tighter government Federal directives creating positive investment in all renewable energy. Significantly advanced markets exist in particular States, such as California, which have had long term deployment programs. The goal of the U.S. Department of Energy SunShot Initiative is to make large-scale solar energy systems at low grid penetrations cost-competitive with other energy sources by 2020.

PV research and development at the National Renewable Energy Laboratory (NREL) focuses on (1) boosting solar cell conversion efficiencies, (2) lowering the cost of solar cells, modules, and systems, and (3) improving the reliability of PV components and systems. NREL's PV effort contributes to these goals through high-impact successes in fundamental research, advanced materials and devices, and technology development.

NREL PV research covers the following wide range of topics.

- Measurements and Characterization. Cell and Module Performance; Analytical Microscopy and Imaging Science/Analytical Microscopy; Interfacial and Surface Science/Surface Science; and Electro-Optical Characterization.
- Chemistry and Physics of Materials and Devices. High-Efficiency Crystalline PV (Silicon; III-V Multijunctions; Hybrid Tandems); Thin Films; and Emerging materials and devices, including Perovskites, Quantum dots, Organic photovoltaics, Carbon nanotubes, and 2-D materials.
- Synthesis and Processing of Materials. III-V Deposition; Nanomaterial Synthesis; Thin-Film Processing/Thin-Film Deposition; and Catalysts, Fuel Cells, and Batteries.
- Materials by Design. Materials Discovery; Integrating theory, experiment, and characterization through the Office of Science-funded Centre for Next Generation of Materials by Design.

- Reliability. Laboratory Testing; Field Testing; Engineering; Regional Test Centres.
- Techno-Economic Analysis. Technology Analysis; Market Analysis, in collaboration with NREL's Strategic Energy Analysis Centre.
- Modelling and Theory. Device Modelling; Process Modelling; and High-Performance-Computing Theoretical Studies.
- Manufacturing Prototyping. Webline Activities; Roll-to-Roll Manufacturing for PV, batteries, and fuel cells; within NREL's Process Development Integration Laboratory (PDIL) and the Energy Systems Integration Facility (ESIF).[lxxxvi]

The U.S. Department of Energy Solar Decathlon challenges collegiate teams to design, build, and operate solar-powered houses that are cost-effective, energy-efficient, and attractive. The winner of the competition is the team that best blends affordability, consumer appeal, and design excellence with optimal energy production and maximum efficiency. The first Solar Decathlon was held in 2002; the competition has occurred biennially since 2005, with the next Solar Decathlon planned for 2017 in Denver, Colorado.

This program is one of the U.S. Department of Energy's most successful outreach efforts, the Solar Decathlon helps accelerate the adoption of energy-efficient products and design. The program demonstrates to the public the comfort and affordability of homes that combine energy-efficient construction and appliances with off-the-shelf renewable-energy systems. It quickly established a worldwide reputation as a successful educational program and workforce development opportunity for thousands of students. Subsequently the program expanded to Europe, China, Latin America, and the Middle East to involve an additional 94 teams and nearly 12,500 participants through Solar Decathlon Europe 2010 (Madrid, Spain), Solar Decathlon Europe 2012 (Madrid, Spain), Solar Decathlon China 2013 (Datong), Solar Decathlon Europe 2014 (Versailles, France), and Solar Decathlon Latin America and Caribbean 2015 (Santiago de Cali, Colombia).[lxxxvii]

Observation 19: *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.*

A Technology and Candidate Assessment

General

The assessment by economies demonstrates that to varying degree there is a large number of complimentary projects and initiatives in APEC economies that could influence the SPESS project. There are examples worldwide of integrated emergency shelter and solar designs with IKEAs "Refugee House" described in Case Study 3 leading the way from concept to widespread implementation in 2015.

The SPESS project can stimulate different sections of product life cycles to build a technology based framework for continuing technology pathways in integrated solar and emergency shelter design production and delivery.

Solar

Solar PV and off grid applications can transform the lives of those people currently deprived of access to electricity, during and after disaster who cannot rely on their grid. Solar cooking and solar water heating integrated with shelter solutions can also provide significant contribution to raise the living standards in developing economies beyond the impact of the disaster. Even in countries with well-developed energy systems, solar technologies can help ensure greater energy security and sustainability.

Some key assessment criteria for the applicability of solar energy in disaster response identified from the assessment of disaster requirements earlier in this report are:

- 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 traumatised 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.

Some of the key organisations leading in solar research identified in the economy assessments that are able to contribute to SPESS (but not limited to) are:

- Australia: The Commonwealth Scientific Industrial Research Organisation, The Australian National University Energy Change institute and UNSW the School of Photovoltaic and Renewable Energy Engineering.
- Brunei Darussalam: The University of Brunei Darussalam.
- The Republic of the Philippines: Solar Energy cell of the De La Salle University Manilla.
- Canada: The Canadian Governments Canmet ENERGY and the University of Toronto Institute of Sustainability.
- China: China National Renewable Energy Centre (CNREC), and industrial research through companies such as Trina solar and Suntech. Tianjin University is the key promoter, of the APEC Sustainable Energy Centre.
- Hong Kong: The Hong Kong Polytechnic University.
- Japan: The Osaka University Research Centre for Solar Energy Chemistry and JSystems-space.
- Singapore: Solar Energy Research institute of Singapore.
- New Zealand: University of Auckland and University of Waikato.
- Korea: The Korean Institute of Energy and Industry such as Hyundai and LG Electronics.
- Chinese Taipei: Taipei Industrial Technology Research Institute.
- United States: National Renewable Energy Laboratory, DOE Solar Decathlon, and Industry.

Further advances in solar technologies are under way. Thin film cells, which are made from compounds like cadmium telluride, copper indium gallium arsenide (CIGS), or amorphous silicon (A-Si), are being developed for PV use. These advances reduce the amount of material used in creating solar cells and can be “printed” on flexible surfaces, potentially reducing cost and increasing ease of application. Researchers are also working with nanomaterials, including polymer films that are less than 100 nanometres thick that could replace silicon cells and nanomaterial-based coatings that repel water and that prevent dust and debris from sticking to panels.

A range of novel concepts are under investigation and are expected to capture an increasing share of the PV market over time. Some of these, such as nano silicon cells, aim to combine the high efficiencies of crystalline products with the low manufacturing cost of thin films. Others, such as organic cells use entirely different processes and may form the basis of very low cost PV products, even if efficiencies remain relatively low. These technologies may compete with the ‘power modules’ of generation 1 and 2, or provide a new range of PV applications, built into consumer products, clothing or building materials and replacing batteries in a wide range of appliances. Hence, the emphasis may be on integration, aesthetics and low cost more than on efficiency and long life.

SLIVER solar cell technology was developed at the Australian National University and is being commercialised by Transform Solar in Boise, Idaho for use in low cost photovoltaic panels. SLIVER cells are thin mono-crystalline silicon solar cells fabricated using standard fabrication procedures. However, instead of fabricating one solar cell from a single silicon wafer, several thousand small (1cm2) cells are produced from a single wafer. A single 200 mm diameter wafer can supply sufficient solar cell area to populate a 1 m2 photovoltaic module

Completed SLIVER solar cells have dimensions of length 5-10 cm, width 1.5 mm, and thickness 40-60 µm. Unlike conventional crystalline silicon solar cells, SLIVER cells are naturally flexible because they are thin. This flexibility allows them to be incorporated into flexible and conformable modules which can power portable electronic devices.

Since they are fabricated from mono- crystalline silicon, SLIVER cells have high and stable efficiencies. In module format using Transform's commercial SLIVER cells the efficiency is currently 13%, with this expected to rise to 15% over the next 2 years, and 17% thereafter. Laboratory cells have reached 20%.

Along with their flexibility and high efficiency, SLIVER cells have several other properties which are advantageous for lightweight, flexible, portable electronic devices. They are lightweight (leading to high power-to-weight ratios and high power-to-volume ratios); perfectly bifacial (they accept sunlight equally well into either face); and their small size and elongate form factor allows battery charging voltage to be reached in a small area (a few cm2). Multiple parallel interconnections within modules confer substantial demonstrated robustness against partial shading and puncturing.

SLIVER silicon solar cells have the advantages of high efficiency, performance stability and non-toxicity inherent in the use of single crystal silicon. In addition, the cost is low because SLIVER cells in large numbers directly from the Boise, Idaho production line of Transform Solar.

At the Hong Kong Polytechnic University researchers combined three layers of materials to maximise efficiency. The main layer is perovskite, a mineral composed of calcium and titanium, which absorbs a broad range of the visible light spectrum and conducts electricity well. It is paired with a bottom layer of silicon, a traditional solar panel component which complements perovskite by absorbing a different set of wavelengths. Products made of pervoskite tend to have defects, however, which hinder lifespan and stability, although the impact is minimised by treating the panels with dry oxygen at low temperatures.

Dye sensitised solar cells (DSC) solar cells use photosynthetic principles to capture light and redox based cell structures to produce electricity. They are also referred to as Graetzel cells, after the original developer, Michael Graetzel. Small area modules are already being used for specific purpose applications, including mobile phone and other battery chargers, sometimes integrated into clothing, otherwise coated onto flexible and lightweight substrates for mobile use. The ability to operate in low light conditions, even indoors, and to be made in a range of colours, provides opportunities for new applications. Laboratory efficiencies of 11 % have been achieved, and the potential for very low cost and low energy manufacture has seen a significant increase in R&D. Further development of this technology is focussing on different dyes, improved sealing or the use of solid electrolytes to overcome sealing issues, concentrating systems, improving stability and durability.

Organic cells aims to use organic, rather than inorganic materials to absorb sunlight and convert it to electricity. A range of conductive polymers, carbon fullerenes and other materials are being examined, which it is hoped will enable continuous, low cost production processes to be established. Hybrid organic and inorganic cells are also being investigated. Research programs aim to explore new materials, improve efficiency and stability, as well as developing processes that can be used for commercial production.

At the Solar Energy Research Institute of Singapore the Organic Solar Cell Group focuses on the development of the science and technology of solution-processed organic solar cells. The group's R&D work includes: (i) fabrication, characterisation and modelling of the morphological, optical and electrical characteristics of diagnostic cells, (ii) novel materials and device concepts, and (iii) printed solar cells. One novel PV concept investigated at SERIS is solution processed organic solar cells. An emerging mass-production PV technology researched by SERIS are thin-film solar cells based on the CIGS (copper, indium, gallium, and selenium/sulphur) materials system.

Observation 20: *From a technology perspective solar energy research is highly competitive across APEC economies with several leading organisations examining thin film, organic cells and nanotechnologies. This research must be compared to the identified needs for solar energy in disasters and the capabilities of the APEC economies.*

Storage

Distributed energy (that is, using batteries to bring power to areas where wiring or reliable supply is not available) may have a relatively small direct economic impact but have a transformative effect on the lives of people impacted by disaster. Batteries in their various forms constitute the most widely known energy storage technology. Lithium ion (Li-ion) batteries are widely used in consumer electronic devices such as laptop PCs, as well as in electric and plug-in hybrid vehicles. The Li-ion battery market is expected to double in the next four years to $24 billion in global revenue.

Significant performance and cost improvements are also expected in Li-ion batteries over the coming decade. The average cost of owning and operating Li-ion batteries for utility grid applications (a function of multiple variables including battery prices and cycle life) could fall from $500 per MWh to between $85 and $125 per MWh by 2025. This could make Li-ion batteries cost competitive for some grid applications and for providing distributed energy, Other important energy storage technologies include molten salt, flow cells, fly wheels, supercapacitors, and even conventional lead acid batteries (including recycled batteries). Other promising battery technologies that are currently under development but may not be commercially viable by 2025 include liquid metal, lithium-air, lithium-sulfur, sodium-ion, nano-based supercapacitors, and energy cache technology.

At the Chinese Taipei Industrial Technology Research Institute researchers have opened the structure of graphite (i.e., graphitic foam) to speed up the charging/discharging reactions of the battery cell. As a result, the battery cell exhibits great durability as it can stand up to 10,000 charge-discharge cycles without capacity decay, and can be charged within one minute. The graphitic materials used for the battery cell are as flexible and supple as paper, and very stable. The basic component of the liquid electrolyte is aluminium salt, so it is stable at room temperature. The battery can withstand drilling tests during the discharge process and still continue to supply electricity, attesting to its safety.

Three major breakthroughs were achieved in developing the ultrafast rechargeable aluminium-ion batteries: 1. discovery of the perfect combination of aluminium and graphite as the battery cell; 2. the whole battery cell is as supple as paper, and can be mass produced for various demands and product attributes; 3. the stability and durability which make the battery safe even if damaged by an external force. This breakthrough battery technology will compete with the traditional lead acid battery when applied in large energy storage devices, lightweight electric scooters and motorized bicycles. In addition to small smart devices, aluminium-ion batteries could be used to store renewable energy in electricity grids, electric motorcycles and bicycles.

Observation 21: *Storage considerations were not broken out of the* economy *assessment as a specific issues. Storage technologies is a very important driver of the capacity to implement solar solutions in emergency shelter. SPESS must have a technology pathway that is cognisant on the integration of storage into solutions.*

Microgrids

Existing technologies such as microgrids, in concert with proven distributed electrical generation systems generated by solar energy can become a feature of the new smart grid applications in disaster response. ABB, Schneider Electric and Caterpillar are just a few major companies who have identified this all important segment.

A microgrid is a small-scale version of a traditional power grid. It draws energy from clean sources such as wind and solar power, as well as from conventional technology and can be connected to a larger electric grid, but also work independently. The concept of localised power generation is not new as prior to World War II, most utility grids were fairly self-contained, with power plants located close to the markets they supplied. It wasn't until the middle of the 20th century that utility grids became today's sprawling networks where central power generation facilities distribute power to homes and businesses hundreds of miles away. In the last ten years the modern microgrid has emerged as an alternative to the local utility.

The ability to work independently from the larger utility grid, known as "islanding," makes the microgrid attractive to many essential services providers. "Islanding" is in many ways a more sophisticated concept of 'back-up' generation, maintaining power during outages. Microgrids are about integrating and balancing multiple loads and distributed generation resources within a smart micro distribution grid, using powerful software SCADA control systems (microgrid management systems), residential solar, wind energy, battery storage and other types of renewables and storage – such as hot water systems – ensuring that the use of fossil fuel gas and diesel is kept to a minimum

The potential for smart grid technologies with emerging energy storage systems can increase electrical generation and distribution resilience. The widespread deployment of these technologies requires new capabilities in the distribution system as well as integration with overall power system operation. The key issues are the identification and realization of requirements for the technologies themselves as well as the communication, information, protection and control infrastructures that facilitate interoperability and integration of the technologies.

Observation 22: *Microgrids were not broken out of the* economy *assessment as a specific issue. Microgrids are not a first order driver of the capacity to implement solar solutions in emergency shelter. However, microgrids will influence SPESS in the joined up applications of community recovery after disaster. SPESS must have a technology pathway that is cognisant on the integration of solar energy with shelters and the employment of microgrids in disaster affected communities.*

Emergency Shelters

Emergency Shelter is a well-developed part of the UN disaster cluster system, but is considered in terms of logistic suitability rather than the quality of shelter. By comparison to solar energy research there is less research into shelter design. While there are some clever innovations put forward many innovations do not get employed because of the logistic simplicity imperative. Some key assessment criteria for the applicability of solar energy in disaster response identified from the assessment of disaster requirements earlier in this report are:

- The design of the shelter and the materials used are familiar where possible and culturally and socially acceptable.
- The repair of existing damaged shelters or the upgrading of initial shelter solutions constructed by the disaster-affected population is prioritised.
- Alternative materials required to provide temporary shelter is durable, practical and acceptable to the affected population.
- The type of construction, materials used and the sizing and positioning of openings provides optimal thermal comfort and ventilation.
- Access to water supply sources and sanitation facilities, and the appropriate provision of rainwater harvesting, water storage, drainage and solid waste management, complement the construction of shelters.
- Vector control measures are incorporated into the design and materials are selected to minimise health hazards.

Some of the key organisations leading in shelter design and production identified in the economy assessments that are able to contribute to SPESS (but not limited to) are:

- Australia: Shelter Box Australia, Deployed Structures international and Eden Power Inetershelter.
- The Republic of the Philippines: The employment of smart shelters in Tacloban City and Leyte Island's.
- Canada: Weatherhaven, Canadian Red Cross Society Transitional Shelter Project and other smaller innovative niches.
- China: Mege shelters Currently Nanjing Sanchuan Pavilion Mfty, and other smaller innovative niches.
- Japan: Diawa Lease and Shigeru Ban Architects.
- Republic of Korea: Development of 'Love Homes'.
- United States: Sprung Structures and other smaller innovative niches.

Observation 23: *From a technology perspective emergency shelter research is limited across APEC economies with several economies having limited shelter design and production. There are innovative shelters being designed but only in small numbers because these shelters are not employed in high numbers by the UN and international agencies in response to disasters.*

Integrated Solar and Emergency Shelter solutions

SPESS project has been identified to take advantage of the potential to provided integrated solar and emergency shelter solutions. 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.

There are a number of conceptual shelter designs which incorporate solar energy across APEC economies.

Observation 24: *The integration of solar energy with emergency shelter is only now becoming feasible and cost effective. SPESS has an opportunity to embrace an opportunity to further develop emergency shelter and solar integrated solutions to assist disaster recovery.*

Other Considerations for SPESS

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. natural disasters their impact on electricity supply However, this can waste significant investment against threats that may rarely or never occur, whereas resilience strategies can provide better protection with lower cost against uncertain events.

> ***Observation 25:*** *A resilience based approach will allow for a wider view of the value of energy to the value of disaster response, recovery and the APEC Disaster Risk Reduction Framework. In particular, the notion of energy budget can be explored as part of an energy resilient response and the primacy of logistic based solutions can be challenged.*

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.[lxxxviii]

> ***Observation 26:*** *The complimentary nature of build back better programs that employ innovative solar solutions with emergency shelters, APSECs 'smart and sustainable' cities and Rockefeller 100 resilient cities means that a positive reinforcing loop which helps future proof our cities.*

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, subsidising 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 countries.

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.

> ***Observation 27:*** *The SPESS project cannot be constrained by attempting to solve the complexity of all energy governance in APEC. Indeed energy governance is not something which can be solved but the implementation of SPESS must identify if particular governance arrangements or policy will prevent implementation of SPESS.*

Building Investment and Partnerships

Business and private sector organisations 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 organisations, such as World Food Programme (WFP) and OCHA, have contracted private sector organisations 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 country to help organise 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 countries of the APEC could be utilised not only for research and development, but to supplement appointments with various disaster organisations and institutes.

> ***Observation 28:*** *The SPESS project can take advantage of building many new partnerships that have not yet been established in the humanitarian network.*

Enhancing Humanitarian Innovation

The International Humanitarian Network has recognised that many organisations 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.[lxxxix]

> ***Observation 29:*** *The SPESS project can take advantage of the UNHCR innovation program noting that the IKEA 'Better shelter' project was supported through the UNHCR Innovation Incubator.*

Conclusion

This literature survey set 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).

The majority of the report is the assessment of emergency shelter and solar research capability in the 12 APEC economies. This assessment is complimented by a technology examination across the 12 APEC economies. A collection of 29 observations made during the report appear at the end of this conclusion. These observations will assist the reader in gaining a quick understanding of the information contained in the report.

The 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.

There are a number of conceptual shelter designs which incorporate solar energy across APEC economies.

This report recommends that SPESS project consider several other issues in the project:

- An Energy Resilient Tool,
- Building Smart and Resilient Cities,
- Understanding Governance,
- Embracing Investment and Partnerships, and
- Enhancing Humanitarian Innovation.

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. The SPESS project can make a difference to people lives and livelihoods by re-establishing communities through the provision of shelter and energy.

Collected Observations

Observation 1: The SPESS project has the potential to provide an example of advanced science assisting with direct applications within the complex interconnected international disaster management system.

Observation 2: Current emergency shelter design and delivery is a logistics system which is designed to push forward pre-defined and pre-stored solutions. While this approach recognises the need to have well developed solutions there are always better shelter systems coming to market. UNHCR who is responsible for the shelter cluster with the IFRC has recognised the need for humanitarian innovation creating an innovation cell. The shelter standards rarely refer to energy needs other than as a preferable siting need.

Observation 3: Beyond the scope of this project but important in setting the correct conditions for SPESS is that currently energy considerations in disaster response rest on traditional spot electricity generation while repairs to existing grid is made. An 'energy budget' strategy will complement and assist SPESS. There is an opportunity to present SPESS as an integrated solution to energy needs

Observation 4: The key criteria developed for solar in relation to disaster response requirements should guide SPESS assessment of solar technology integrated with emergency shelter design. These are not the considerations for applying solar energy in normal conditions.

Observation 5: The IKEA 'Better Shelter' is a significant development because it represents a fully designed and implemented integrated solar energy and shelter solution. The nature and type of the solar solution could be improved. SPESS may wish to examine the design and perhaps invite IKEA to be part of the project.

Observation 6: Military Operational camps with embedded energy sources such as solar are likely to be world leading in the integrated shelter and energy design. Civil-military engagement is an important element of disaster response in APEC economies and the management of shelter is an important component of civil-military disaster response.

Observation 7: This project will need to understand the relative and changing conditions of development identified through the SDGs and Sendai Framework, and in particular the appropriate technologies in place in developing countries. SPESS project will need be specifically tailored to the capacity building needs of APEC's developing economies, featuring strong developing economy involvement in the planning and executing of the project.

Observation 8: Australia has some local emergency shelter design experience, with small innovations but most shelter expertise resides largely in industry and NGOs. Australian government organisations 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.

Observation 9: 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.

Observation 10: 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.

Observation 11: 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.

Observation 12: Hong Kong, China has the Asia Disaster Preparedness Institute which is focussed 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.

Observation 13: 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.

Observation 14: 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.

Observation 15: Korean emergency shelter has been focussed 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.

Observation 16: 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.

Observation 17: 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.

Observation 18: 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.

Observation 19: 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.

Observation 20: From a technology perspective solar energy research is highly competitive across APEC economies with several leading organisations examining thin film, organic cells and nanotechnologies. This research must be compared to the identified needs for solar energy in disasters and the capabilities of the APEC economies.

Observation 21: Storage considerations were not broken out of the economy assessment as a specific issues. Storage technologies is a very important driver of the capacity to implement solar solutions in emergency shelter. SPESS must have a technology pathway that is cognisant on the integration of storage into solutions.

Observation 22: Microgrids were not broken out of the economy assessment as a specific issue. Microgrids are not a first order driver of the capacity to implement solar solutions in emergency shelter. However, microgrids will influence SPESS in the joined up applications of community recovery after disaster. SPESS must have a technology pathway that is cognisant on the integration of solar energy with shelters and the employment of microgrids in disaster affected communities.

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Observation 28: The SPESS project can take advantage of building many new partnerships that have not yet been established in the humanitarian network.

Observation 29: The SPESS project can take advantage of the UNHCR innovation program noting that the IKEA 'Better shelter' project was supported through the UNHCR Innovation Incubator.

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