APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): Evaluation of the Role of Village Power Applications in Response to the Tsunami Recovery

Expert Group on New and Renewable Energy Technologies
APEC Energy Working Group

November 2007

EWG 03/2006A
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APEC Publication Number APEC#207-RE-0

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ACKNOWLEDGEMENTS

The author would like to thank several people who greatly contributed to the work in this project.

Special thanks are due to Mr. Harvey Mayor, at the Energy Efficiency and Renewable Energy Program, US Department of Energy, who was the project overseer for his continued support throughout the project.

The author very much appreciates the assistance of Dr. Asclepias R.S. Indriyanto, the Executive Director, and her staff, at the Foundation of Indonesian Institute for Energy Economics (IIEE) in providing the information regarding tsunami disaster response and community reconstruction projects in Indonesia. FIIEE also contacted the government officials and organizations involved with the tsunami activities in Indonesia, and worked as a partner with TDP in this project. Their assistance contributed significantly to the project.

Thanks are also due to government officials, utilities, and various organizations in Thailand who responded to the project questionnaire and provided useful information on tsunami activities in Thailand. My sincere appreciations go to Mr. Anucha Mokkhavesa, the Director General, Mr. Pongpow Ketthong, the Deputy Director General, and Mr. Suporn Ratananakin, the Director of Research and International Cooperation Bureau, of the Department of Disaster Prevention and Mitigation; the managers of the Provincial Electricity Authority in Phuket, Phang Nga, Krabi, Ranong, Satun and Trang; Mr. Prayad Kruangpradit, the Director of Personnel Development Department, and Mr. Prasan Mepramool at the New & Renewable Energy Section, System Development Division, both of the Provincial Electricity Authority; Mr. Ruangdeth Punduang, the Bureau of Energy Development, and Dr. Boonrod Sajjakulnukit, Project Coordinator, of the Department of Alternative Energy Development and Efficiency; Dr. Samai Jai-in at the National Metal and Materials Technology Center, and Mr. Phat Kulphaichitra, Secretary General of the Amateur Radio Society of Thailand. Without their participation in the project, this report could not have been completed.

The author would also like to thank Dr. Allen Clark at the Pacific Disaster Center in Hawaii, Mr. Brian Yanagi at the International Tsunami Information Center in Hawaii, and Dr. Cherdsak Virapat, Chief, International Coordination of Thailand's National Disaster Warning Center, all of whom provided information on the tsunami warning systems which was very useful for the project.

The author would like to also acknowledge Ms. Elizabeth Grossman for her editorial work in this report.

All remaining inaccuracies in the report are the sole responsibility of the author.

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Chapter 1

Introduction

1.1 Overview on APEC 21st Century Renewable Energy Development Initiative (Collaborative VI)

The Asia-Pacific Economic Cooperation (APEC) 21st Century Renewable Energy Development Initiative was launched by the United States at the fourth APEC energy ministers meeting in San Diego, California in May 2000, at which time it was endorsed by all of the energy ministers. The purpose of the initiative is to advance the use of renewable energy for sustainable economic development and growth in the APEC region. The initiative addresses the principal objectives of the APEC Energy Working Group by fostering a common understanding of regional renewable energy issues, facilitating trade and investment in renewable energy technologies and services, and reducing the environmental impact of the energy sector through the application of renewable energy technologies. It also addresses the APEC energy ministers' recommendations regarding the use of renewable energy for sustainable development and diversification of energy supplies. Furthermore, it addresses, from the perspective of renewable energy technology applications, the six priority economic and technical cooperation areas identified by APEC leaders at their meeting in the Philippines in 1996, relating to developing human capital, fostering safe and efficient capital markets, strengthening economic infrastructure, harnessing technologies of the future, promoting environmentally sustainable growth, and encouraging the growth of small and medium-sized enterprises.

The APEC 21st Century Renewable Energy Development Initiative has been implemented by the Expert Group on New and Renewable Energy Technologies (EGNRET). The EGNRET has used this initiative as a base to link its projects with a series of collaborative efforts that specifically address the renewable energy-based needs and issues of individual APEC member economies. Projects developed under the initiative take into consideration renewable energy infrastructure, development needs, training requirements, needs for analysis tools and methods, policy formulation, financing, joint-venture development, and the removal of trade barriers. There are currently nine such collaborative efforts. The project entitled, *Evaluation of the Role of Village Power Applications in Response to the Tsunami Recovery Effort* was launched under the APEC 21st Century Renewable Energy Development Initiative, Collaborative VI: Renewable Energy Technology Applications. This Collaborative is being led by the United States.

The objective of Collaborative VI is to identify and demonstrate potential applications of renewable energy technologies in the APEC region. Project areas under this Collaborative include hybrid renewable systems for schools in rural areas, renewable energy technology parks, and best practices for biomass applications. Collaborative VI also aims to establish a database on renewable energy technology applications and best practices, and to hold workshops for information exchanges. Some completed projects undertaken as part of Collaborative VI are *Monitoring and Assessing the Design,* *Operation and Performance of an Ocean Thermal Energy Conversion (OTEC), Workshop on Advances in Electricity Storage in Support of Distributed Renewable Energy-Based Systems*, and *Development of a Sourcebook of Hydrogen Codes and Standards for APEC member economies*.

1.2 Project Background

The *Evaluation of the Role of Village Power Applications in Response to the Tsunami Recovery Effort* project was supported financially by the APEC Secretariat and implemented by EGNRET as part of the APEC 21^{st} Century Renewable Energy Development Initiative Collaborative VI: Renewable Energy Technology Applications.

This project was endorsed by all APEC EGNRET representatives in 2006 after the tsunami catastrophe in the Indian Ocean in December 2004. The tsunami caused severe damage to countries across South and Southeast Asia, including the three APEC member economies—Indonesia, Malaysia, and Thailand. Over 200,000 people were killed or lost, more than a million people became homeless, and hundreds of villages along the coastline of the Indian Ocean were destroyed. The tsunami caused much more severe damage in Indonesia than in Thailand and Malaysia. In Indonesia, it devastated an 800 kilometer coastline of Aceh, on the northern part of Sumatra Island. The earthquakes before and after the tsunami also caused massive damage throughout the island of Nias, an island about 125 kilometers west of Sumatra. The death toll in Indonesia was estimated at over 150,000 people. In Thailand, the tsunami damaged six provinces along the Andaman coast, including Phuket, Phang Nga, Krabi, Ranong, Satun, and Trang. More than 8,000 people were killed and over 407 villages along coastal areas were damaged, 47 of which were almost completely destroyed. The tsunami damage in Malaysia was much less extensive than in Indonesia and Thailand. In Malaysia, only 68 people were killed, with hundreds injured in the aftermath.[1] Because the epicenter of the earthquake was on the western coast of Sumatra, Malaysia was shielded from the worst of the tsunami. The most damaged areas of Malaysia were the northern coastal areas and outlying islands like Penang and Langkawi.

The widespread damage from the tsunami posed unique logistical and time-sensitive challenges for the affected economies. There was no doubt that village power applications could be an important part of the tsunami recovery effort and could be quickly mobilized in disaster response activities. Village power technologies could also be utilized in many different applications for reconstruction of communities after the tsunami. This project was designed in order to facilitate a full understanding of the role of village power technologies in the tsunami recovery efforts in the three economies.

1.3 Project Objectives

The objectives of this project are

(1) to examine the role of village power applications in the tsunami recovery effort,

[1] Asian Disaster Reduction Center (www.adrc.or.jp)

(2) to identify the obstacles which might have been present that prevented greater use of these applications to benefit APEC member economies, and
(3) to document lessons learned that could serve as a basis for developing guidelines for the future rapid utilization of village power systems in the aftermath of another natural disaster in the APEC region.

The product of the project is a concise guide of available off-grid energy technologies that can be used to prepare for future disaster responses. The project report will also provide a basis for developing guidelines for the future rapid utilization of village power systems in the aftermath of another natural disaster in the APEC region. The beneficiaries of this project are the APEC government agencies who must respond to unanticipated disasters and their citizens who are directly impacted by the disasters. Identifying available village power technologies for disaster responses and reconstruction activities, as well as the lessons learned from the past and existing village power programs will facilitate future disaster recovery efforts.

1.4 Project Activities

The project focused on an evaluation of the role of village power applications in response to recovery efforts in three APEC member economies affected by the tsunami in December 2004: Indonesia, Malaysia, and Thailand. The project was conducted in six phases:

Phase 1: Review village power applications utilized by the tsunami affected economies

In the first phase of the project, TDP reviewed village power applications that the tsunami affected APEC economies—Indonesia, Thailand, and Malaysia—have utilized both for urgent response and for permanent reconstruction. The work was conducted through direct communications with local researchers, government officials, and organizations involved with tsunami recovery efforts and reconstruction, and by reviewing available reports and documents on tsunami recovery activities and plans in the three economies. In Indonesia, TDP worked with the Foundation of Indonesian Institute for Energy Economics (or Yayasan Institut Indonesia untuk Ekonomi Energi—IIEE), an Indonesian non-governmental organization. IIEE worked cooperatively with TDP in providing information regarding Indonesia's tsunami recovery efforts.

Phase 2: Review obstacles that prevented the adoption of village power applications

Phase 2 activities focused on reviewing obstacles that prevented the adoption of village power applications—both adoption for urgent response and adoption for permanent reconstruction. TDP developed a project questionnaire and sent it to all parties involved in tsunami responses in the three economies. The questionnaire asked about village power technologies that have been used for tsunami recovery efforts in their economies, the obstacles that prevented adoption of village power technologies, and problems and successes stories related to the use of village power technologies.

Phase 3: Review various village power programs and identify lessons learned

In Phase 3, TDP reviewed past and present village power programs and identified lessons learned that could be shared with the tsunami-affected economies and with other APEC member economies. TDP conducted this task by drawing upon materials from APEC related village power activities such as the recently completed project *APEC 21st Century Renewable Energy Development Initiative (Collaborative I): Technical Workshop to Support Village Power Applications (EWG 04/2003)*, and other national and international village power activities. TDP also examined lessons learned from village power projects undertaken by the United States' National Renewable Energy Laboratory (NREL). NREL's Renewables for Sustainable Village Power Program contains information and lessons learned from over 140 village power projects in over 30 countries that could be applied to the tsunami-affected areas.

Phase 4: Develop recommendations to increase the utilization of village power technologies

TDP used the information gathered in Phases 1 through 3, as well as the information acquired from manufacturers about commercially available village power technology packages, to develop recommendations on the technologies that an economy should consider adopting in the aftermath of a natural disaster and for community reconstruction. This information was also used to develop recommendations for increasing the utilization of village power technologies. All commercially available village power technologies were examined, especially those commonly used for electrification, lighting, and communications.

Phase 5: Develop a draft final report

TDP developed a draft final report based upon information gathered in Phases 1 through 4. The draft report was circulated to EGNRET members and other key stakeholders contacted for comments.

Phase 6: Prepare and disseminate a final report

Upon receipt of the comments from EGNRET and stakeholders, TDP finalized the report and disseminated it to EGNRET contact points and to the APEC Secretariat.

The final project report consists of seven chapters. Chapter 1 is an introduction, which discusses about the APEC 21st Century Renewable Energy Development Initiative, and explains the project background, project objectives, and project activities. Chapter 2 reviews the utilization of village power applications for tsunami recovery efforts in Indonesia, Thailand and Malaysia. Chapter 3 investigates the obstacles to adopting village power technologies both for urgent response and for permanent reconstruction projects in Indonesia, Thailand, and Malaysia. Chapter 4 identifies and assesses lessons that could be learned from the past and present village power programs in various APEC member economies, and also from the village power programs in the Pacific Islands.

Recommendations on village power technologies for use in both urgent response situations and permanent reconstruction are presented in Chapter 5, and policy recommendations to promote greater utilization of village power technologies are presented in Chapter 6. Chapter 7 contains conclusions and the proposed next steps for the project.

Chapter 2

Village Power Applications for Tsunami Recovery Efforts

This project focused on the use of village power technologies such as solar energy, wind energy, micro-hydropower, and biomass technologies to provide off-grid electricity at a village level that is normally less than 10 kilowatts (kW) of power capacity. These village power technologies include portable photovoltaic (PV) systems that can be used during power outages to power shelters, radio systems, emergency telephones or charge batteries, or hybrid systems of PV and wind or PV and diesel generators that can be utilized to provide electricity for remote villages.

Chapter 2 reviews the utilization of village power applications for tsunami recovery in Indonesia, Thailand and Malaysia.

2.1 Village Power Applications for Tsunami Recovery in Indonesia[2]

Village Power Applications for Emergency Response

The state-run National Disaster Relief Agency or Bakornas PBP (Badan Koordinasi Nasional Penanggulangan Bencana dan Penanganan Pengungsi) was responsible for rescue and emergency relief in Indonesia. In the 2004 tsunami, due to its large scale, the search and rescue efforts were also conducted by the Indonesian military along with military forces from various countries, in addition to local and foreign volunteers.

Diesel generators are commonly used to provide off-grid electricity in Indonesia during emergencies. After the tsunami, the Christian Reformed World Relief Committee (CRWRC) set up a tsunami relief response program called GenAssist. With a grant from the Canadian International Development Agencies (CIDA), GenAssist provided “generator setups” or “gensets” for emergency lights for 1,460 households in 19 villages in Blangmee and Cot Mukim in Aceh Besar from shortly after the tsunami destroyed the area until proper infrastructure was built five months later. Floating diesel power plants located in coastal Aceh were also an important source of electricity supply during the tsunami emergency period.

PV-Powered Emergency Telephones

The only village power application used for tsunami emergency response in Indonesia was the PV portable system deployed to power emergency telephones. Seven PV-powered public phones were installed in Nangroe Aceh Darussalam, northern part of Sumatra, to coordinate emergency response activities. A telephone unit was composed of two solar panels, with capacity of 50 watt peak (Wp) each, and a 70 amp-hour battery. The activity was part of a program called Solar Satellite Public Phone Installation in Disaster Area and was operated in partnership with the Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi—BPPT),

[2] Information from the Foundation of Indonesian Institute for Energy Economics

PT.Yuasa Indonesia (a wet-battery producer), the Directorate General of Post & Telecommunication (Dirjen Postel), and PT.PSN (a private satellite telecommunications company). The program was designed to provide technical assistance and satellite-based PV communication equipment in the disaster areas.

Village Power Applications for Community Reconstruction

Aceh and Nias, the main tsunami affected states in Indonesia, were relatively poor states prior to the disaster. Only about 60 percent of Aceh's households had access to electricity, and power outages were common. There was insufficient power generation and transmission capacity in Aceh since its power system was built as an integral part of the North Sumatra power system. Most power in Aceh was supplied either from the North Sumatra grid or by small diesel powered generators. The system was fragmented and lacked economies of scale.[3] The thirty year long conflict in Aceh, during which almost 15,000 people died, complicated the development in Aceh. The tsunami significantly damaged the distribution networks in Aceh. However, the transmission line connecting Banda Aceh, the capital of Aceh Province, to Medan was unaffected and damage to generation plants including Banda Aceh's Luengbata plant was relatively small. The isolated diesel units that served the rural areas on the west coast were also little affected. In the rehabilitation stage, there were temporary measures to power the affected areas, mostly using scattered small-scale diesel generators. On Nias Island, another area that was badly damaged by the tsunami, the demand for electricity is rather small and it has been supplied by small-scale diesel generation. The rehabilitation and reconstruction focused on fixing damage to the existing power system.

As a peace agreement was signed between the Government of Indonesia and the Free Aceh Movement (Gerakan Aceh Merdeka or GAM) in August 2005, progressive recovery of Aceh in infrastructure reconstruction and community redevelopment is fully expected, especially in the GAM affected areas.

In April 2005, the Indonesian government established the Badan Rehabilitasi dan Rekonstruksi (BRR), or the Aceh-Nias Rehabilitation and Reconstruction Agency, to coordinate and oversee the rehabilitation and reconstruction of Aceh and North Sumatra. The reconstruction is being implemented in three phases: Phase 1: Emergency relief to save lives (March 2005); Phase 2: Rehabilitation to reestablish services at minimum standard (April 2005 – June 2006), and Phase 3: Comprehensive reconstruction of whole communities and infrastructure (July 2006 to December 2009).[4]

The village power applications that have been adopted for community reconstruction in Indonesia include off-grid solar electric systems, a micro-hydropower system, an off-grid

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[3] Indonesia: Preliminary Damage and Loss Assessment, The December 26, 2004 Natural Disaster, A Technical Report Prepared by BAPPENAS and The International Donor Community, The Consultative Group on Indonesia, January 19-20, 2005.

[4] "*Rebuilding Tsunami Affected Areas of Asia*", see www.advancecairns.com/industry/fnqski/tsunamiupdate.htm

solar and wind hybrid system, and solar powered tsunami early warning systems. None of these activities were, however, developed by the BRR.

Off-Grid Solar Electric Systems

The off-grid solar electric systems were installed as part of the Bakti Technology Operation Project conducted by the Ministry of Research and Technology in cooperation with other institutions including the Agency for the Assessment and Application of Technology (BPPT), the National Institute of Science (Lembaga IIlmu Pengetahuan Indonesia—LIPI), Bakosurtanal, the Indonesian Association of Geologists (Ikatan Ahli Geologi Indonesia—IAGI), the Indonesian Society of Sanitary and Environmental Engineers (Ikatan Ahli Teknik Penyehatan Lingkungan Indonesia—IATPI), Bank Rakyat Indonesia (BRI—a state-owned bank), PLN (Perusahaan Litrik Negara—a state-owned electricity company), and PT Medco. The project was implemented in early 2005 to provide electricity to local communities in Meulaboh and Calang (areas in Nangroe Aceh Darussalam, northern part of Sumatra). A total of 60 off-grid solar electric systems were installed.

Micro-hydropower

A micro-hydropower plant was installed between 2005 and 2006 at Krueng Kala in Aceh Besar District with a 3 billion Indonesian Rupiah budget from the Corporate Social Responsibility Fund of PT Coca Cola Indonesia. The project partners with PT Coca Cola Indonesia were Yayasan Nurani Dunia and Yayasan IBEKA—both are NGOs. The project activities included building a 40-kilowatt micro-hydropower generation facility and other parallel activities, including the development of modular and permanent schools. The power plant is providing electricity to 200 households, as well as lighting for public buildings such as schools and mosques, and empowers local residents through cooperative activities. The power plant is being operated by the Tuah Krueng Kala Sejahtera Cooperative.

Solar/Wind Power Hybrid System

A hybrid system of solar and wind power has been utilized in the Rebuilding Lamreh Village (RLV) project. The RLV project was implemented at Lamreh village in Aceh Besar district with funds from the Soroptimist International of Jakarta, the Netherlands Red Cross and also some private donors. The objectives of the project were to provide proper housing for Lamreh villagers, improve the welfare and quality of life for all Lamreh villagers, ensure that all pre-school and primary school aged children had access to schooling again, and to train Lamreh villagers to achieve sustainability beyond the life of the immediate reconstruction project. The RLV project activities included the establishment of public facilities such as a library, community hall, women's centre, and health clinic, the reconstruction of 200 houses in four Lamreh hamlets, and establishment of a kindergarten, primary school and playground for residents. The project also included an arrangement for volunteer-conducted capacity building activities for local Lamreh villagers in waste management systems, environmental management, health and hygiene management, teacher training, and other important areas. As part of the project, solar and wind turbine systems were installed to electrify the village's rebuilt public health clinic. Electricity for the whole Lamreh village is provided by Perusahaan Listrik Negara (PLN), the state-owned electricity enterprise, with the exception of the electricity utilized in the health clinic that is provided by a low-cost and low-maintenance solar and wind hybrid system.

Solar-Powered Tsunami Early Warning Systems

After the 2004 tsunami, Indonesia set up a tsunami warning headquarters, and ten regional tsunami warning centers along the southern coast islands from Aceh (western part of Indonesia) to Merauke (eastern part of Indonesia). The tsunami warning centers were equipped with solar-powered tsunami early warning systems. The projects were conducted by the Geophysics & Meteorology Agency (Badan Meteorologi dan Geofisika—BMG), the Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi—BPPT), and the Bakosurtanal, with funds from the Indonesian government and also from Germany, Japan, China, the United States, and France. The project aims to establish a mechanism that will minimize the impacts of future tsunami disasters, to analyze and set up models for the sea environment, to develop mechanisms for transparency in sharing and coordination of disaster information among related institutions, and to handle immediate responses to policy makers on conducting evacuation and post-disaster activities. The project activities include assigning roles and functions to related institutions responsible for handling impacts of tsunami related disasters, setting early warning information distribution networks and coordination to cope with impacts of tsunami disasters, continuous mapping of sea environmental conditions to provide data for sea spatial planning that would be integrated with land and air spatial planning for handling tsunami impacts, and installing several buoys throughout Indonesian coastal areas vulnerable to tsunamis, in order to identify initial tsunami waves. The project is still ongoing and is scheduled to be completed by the end of 2008.

Future Projects with Village Power Technologies

In addition to the completed and ongoing projects mentioned above, additional village power projects are planned for reconstruction in Aceh and Nias. These include two new micro-hydropower plants to be developed in Nias Island and a hydropower plant in Peusangan, Aceh. In addition, several assessments have been conducted on the possibility of utilizing wind power. The details on these projects are described below:

Micro-hydropower

The United Nations Industrial Development Organization (UNIDO)'s Office for Coordination of Humanitarian Affairs is implementing a program for poverty alleviation and restoring livelihoods on the island of Nias through a micro-hydro based community development center. The objective is to provide electricity to improve the life of Nias Island residents through public participation. At the present stage, the project's activities are identifying appropriate sites and training local young people to operate and maintain the electricity system and community development center.

BRR, the principal government organization responsible for tsunami reconstruction, has indicated that micro-hydro and village electrification are priorities. Based on the Aceh and Nias reconstruction and rehabilitation master plan, the government will build two hydropower plants in Peusangan, Aceh province, with an installed capacity of each plant at 22.1 megawatts (MW). An environmental impact assessment is now being conducted.

The World Bank has provided assistance to Indonesia since the late 1960s to support poverty alleviation. The Kecamatan Development Program (KDP) was the community-driven development program begun in 1998 with support from the World Bank. KDP has assisted communities with infrastructure and livelihood development, and with village electrification mostly through micro-hydro schemes. In early 2007, through KDP, five villages received funds for micro-hydro schemes. However, these five villages are in the mountainous areas of Aceh, and not in the tsunami-affected areas. Since the tsunami devastated Aceh and Nias, the KDP has been expanded with support from the World Bank-administered US$530 million Multi Donor Fund to cover all 6,000 tsunami-affected villages in Aceh and Nias. A team of facilitators and volunteers are serving as a conduit for channeling reconstruction assistance from government, private donors, and NGOs and, most importantly, allowing village representatives serving at the sub-district level to determine their own development needs and funding allocations. An assessment of infrastructure status and social situation is being undertaken in all KDP villages in Aceh. The assessment will list all available village infrastructure and assess levels of damages and needs. Some NGOs are working to provide villagers with recommendations that will take advantage of potential local resources such as micro hydropower.

Wind Resource Assessment

In addition to the micro-hydropower projects in progress, two wind resource assessment and feasibility studies were conducted to examine the possibility of using wind power in the tsunami-affected areas of Aceh and Nias. The first project was conducted during June and July 2006 by DANIDA—Carl Bro als-Energy. The project objectives were to assess the wind conditions in Aceh, provide information concerning the possibility of wind energy development in the region, to produce a numerical wind atlas for the northern part of Sumatra, to determine the benefit of establishing a wind measurement program in the region, and to provide suggestions for appropriate wind power plant sites in Aceh. The other project was a feasibility study for the development of wind energy in Lahewa, Nias Island. The study was funded by the government of Spain and implemented by Soluziona S.A. between December 2005 and April 2007. The project objective was to evaluate whether wind energy can become an alternative to diesel in providing a clean, cost-effective and alternative source of electricity.

Aceh has high geothermal resource potential. Pertamina (the state oil and gas company) identified around 1,185 MWe of potential geothermal power in Aceh Province.[5] However, there has been no development of geothermal resources for current tsunami reconstruction. The current plan for developing 2x20 MW of geothermal power in Seulawah is not progressing due to lack of funding. The local government of Nanggroe Aceh Darussalam (the special autonomous province of Aceh) recently developed tenders for a 45 MW Sabang Geothermal Power Plant. In addition to funding limitations, regulatory and bureaucracy obstacles are also considered significant factors in hampering geothermal development throughout Indonesia.

2.2 Village Power Applications for Tsunami Recovery in Thailand

Village Power Applications for Emergency Response

The agency responsible for disaster relief in Thailand is the Department of Disaster Prevention and Mitigation (DDPM) under the Ministry of Interior. Because of the magnitude of the devastation, emergency relief was also conducted by the entire civil and military apparatus of the Royal Thai Government. The Royal Thai Navy used helicopters and ships to search for and evacuate survivors on affected islands and to deliver essential supplies. Military personnel were also deployed to search for survivors in affected land areas. More than 5,000 soldiers joined 20,000 local officials and volunteers in the rescue operation in the affected areas. Private telecommunications enterprises deployed satellite vehicles to support the communication systems. Crisis coordination centers were set up in every affected province.

Thailand had much less impact from the tsunami than did Indonesia. The power systems in the tsunami-affected areas of Thailand were not destroyed. There was also no damage to generators or transmission systems, only to the local distribution systems, which were fixed a short time after the incident. Hotels and restaurants along the Andaman coastline of Phuket, Phang Nga, Krabi, Satun, Ranong, and Trang were destroyed. However, shops, offices and restaurants in the town areas further inland were not affected. Rescue teams, food, and needed assistance poured into the affected areas in a very short period of time after the tsunami.

Drinking water safety was an issue of greatest concern in the damaged region. Seawater and water from broken sewage systems mixed with clean water in villagers' wells—often used for drinking. Immediately after the incident, trucks loaded with bottled water were sent to affected areas. Later, the government arranged to send thousands of water purification units from a company in Bangkok to affected areas to provide villagers with drinking water. These water purification units were run by electricity. Since the damaged areas were electrified, solar-powered water purification systems were not necessary during that time.

[5] Pertamina, Pertamina Geothermal Development: Resource and Utilization, Jakarta, 2005.

During the immediate tsunami disaster relief in Thailand, no village power technologies – such as portable PV systems–were used to power shelters, to power emergency telephones, or for battery charging.

Village Power for Community Reconstruction

The post-tsunami reconstruction was conducted by various organizations in Thailand. The principal Thai government agency responsible for reconstruction after the tsunami was the Department of Public Works and Town & Country Planning (DPT). The major tasks of the DPT were to renovate all damaged government and public buildings, restore tourist attractions, and to rehabilitate communities. The DPT also constructed several new communities for tsunami victims. In addition to the DPT, many Thai corporate donors and organizations, foreign donors and foundations sponsored housing projects for tsunami victims.

Most of the tsunami-affected areas in Thailand are on electricity grids. The unelectrified areas were only small, remote parts of impacted islands. The Provincial Electricity Authority of Thailand (PEA), a public utility, is responsible for providing electricity to houses in all areas outside the Bangkok Metropolitan Areas. PEA has offices in every province to manage power transmissions, sales and maintenance. Since the tsunami did not severely damage the power system, the PEA staff at its local offices was able to fix the damaged parts of the systems, which mainly involved the distribution systems. Consequently, power was restored to people in those electrified areas within a short time. At the time of the tsunami, the unelectrified houses on the damaged islands were due to be electrified by the end of 2006 as part of the PEA operating plan. Thai government policy in place since 2004 and prior to the tsunami, stipulated that all houses in Thailand would be electrified by the end of 2006. This policy stated that all houses that could be connected to electricity grids would be electrified by a grid connection. Houses that could not be connected to the grids because they were located in national parks, conservation areas, islands or mountainous areas where any construction was prohibited by law, or where extending an electrical grid was cost-prohibitive, would have solar home systems installed at no charge to home owners. All unelectrified houses in the tsunami areas were thus electrified by 2006 (or in some cases at a later date in 2007)—mostly by solar home systems. However, the solar home system electrification in these houses was not undertaken as part of the tsunami reconstruction.

After the tsunami, the DDPM formulated a systematic evacuation plan for communities in the six coastal provinces along Thailand's Andaman coast. Designated evacuation routes were selected and clearly marked to facilitate rapid and convenient evacuation and escape within the shortest possible time. Appropriate evacuation sites were selected. Residents and members of the local community are being educated and made aware of the potential dangers of natural disasters so they will be well prepared and know how to respond to warnings through a series of disaster response drills. The Civil Defense Secretariat Office of DDPM has operated several drills so far. However, not much attention was given to village power technologies that could be used to save lives during disasters.

In 2006 the German government (GTZ) provided financial support to the DDPM to work on an integrated disaster preparation scheme for Thailand. One goal of the project was to prepare residents in disaster-prone regions of Thailand to plan and organize their own disaster prevention systems, based on the principal of community-based disaster risk management (CBDRM). CBDRM focused on having local residents analyze their specific risk situation, work out their own emergency operation plans, install early warning devices, and arrange to coordinate with volunteers and representatives of other regional or local agencies for search and rescue. The second goal of the project was to establish a decentralized disaster prevention scheme and overall disaster management system in DDPM's training curriculum, and to coordinate work among different government agencies to implement the concept of CBDRM in every local community. DDPM selected two pilot communities for practical training in the project. In this project, however, no village power technologies were included. DDPM gave the two participating pilot communities various types of equipment to be used during emergencies but included no renewable energy products.

The Department of Alternative Energy Development and Efficiency (DEDE) under Thailand's Ministry of Energy has worked to support and promote clean energy production and consumption in Thailand. DEDE has been promoting solar energy utilization in Thailand since 1993. Several solar energy projects implemented by DEDE have been completed. These include, solar power systems for battery chargers in 364 unelectrified villages (2.5-3 kW per system) installed between 1993 and 2004, solar power in 183 rural schools and border patrol police schools (2-5 kW per system) installed between 2002 and 2005, installation of mini-grid solar power in five villages (5 kW per system for total of 10 systems) in 2003, solar power for water pumping at 65 locations (1 kW system) in 2003, solar power for health clinics in 36 locations (1 kW system) between 2004 and 2006, solar power for rural educational centers in 80 locations (1.5 kW system) between 2004 and 2005, solar power at army bases and border patrol police stations in 90 locations (255 watts) between 2002 and 2005, and solar power and solar thermal dehydration in 19 locations installed in 2005. An ongoing solar project implemented by DEDE will electrify 400 rural primary schools, with a solar system capacity of 2-5 kW per school. DEDE has set a budget of 552 million baht for the five year operation. The project began in 2003 and is scheduled to be completed in 2010. These projects are, however, not related to tsunami reconstruction.

There were three village power projects related to tsunami reconstruction in Thailand; all were solar power projects.

Solar Home Systems

One tsunami reconstruction project that utilized village power applications was the installation of a solar home system at a house on Kho Khao Island. Kho Khao is an island in Phang Nga province about one kilometer from the mainland. Several hundred people at Kho Khao Island died and half of the island was severely damaged by the tsunami. Most houses there were electrified. There was only one house that was not electrified because it was located at the far end of the island and was about 3 kilometers away from the electricity grid. Technology Development Partners Inc., with support from the U.S. Department of Energy, worked with Thailand's National Science and Technology Development Agency (NSTDA), Ministry of Science and Technology, and the Dr. Thiam Chokwatana Foundation, a Thai charitable organization, to install a solar home system for that house.[6]

The house was a two-storied building and was owned by a fisherman's family of four people. The team interviewed the homeowner to understand the family's lifestyle, and estimated the family's electricity needs. The family's maximum electricity consumption was estimated to be about 170 watts per hour. The electricity would be used for five fluorescent light bulbs of 18 watts each, for a total of 90 watts per hour, one 14-inch color TV, using a total of 50 watts per hour, and one fan using total of 30 watts per hour. It was estimated that the family used electricity for about five hours a day. Thus their total use of electricity per day was about 850 watts.

Based on the estimated electricity needed, a solar system comprising of the following components was installed at the house:

- 400-watt PV panels (8 PV panels, 50 watts each)
- 1 Battery for storage, 12 V 100 Ah
- 1 Charge controller 20 A, 12 V to 24 V
- 1 DC-AC Inverter, 1 kVA, 48 V to 220 V

The system was installed in December 2005. There was one problem reported after about a year of installation: the system inverter was broken. After NESDA replaced the inverter, the system has been working normally.

Solar Power Electrification[7]

A solar power electrification system will be installed at Kiertpracha School at Prathong Island, in the Kuraburi district of the Phang Nga province. This school was located in the area in Thailand hardest hit by the tsunami. It was unelectrified before the tsunami incident. DEDE has set a budget to install a solar system at the school. At the time this report was being prepared, DEDE had called for bidding from local private companies to install the system. The system was set to include solar panels with a total capacity of not less than 2500 Wp, a charge controller, batteries, standalone inverter and AC line, 1 phase, and 2 wires of 220 V, 50Hz.

[6] The project report, Sustainable Redevelopment of Communities Destroyed by the Tsunami, can be downloaded at http://www.technologydevelopmentpartners.org/pages/Tsunami%20project%20Report.pdf

[7] Information from the Department of Alternative Energy Development and Efficiency

Solar-Powered Tsunami Warning Systems [8]

The National Disaster Warning Centre (NDWC) was officially inaugurated in Thailand in May 2005, five months after the tsunami disaster. The NDWC functions as a centralized information center receiving, monitoring, processing, and relaying critical information on impending natural disasters. NDWC is a critical component of a fully integrated tsunami Early Warning System launched in Thailand. NDWC, with technical assistance from the U.S. National Oceanic and Atmospheric Administration (NOAA), installed the two DART (Deep Ocean Assessment and Reporting of Tsunamis) buoys in the Indian Ocean to monitor sea pressure and activity, and relay wave movements to surface buoys. The surface buoy monitors upper-level conditions and relays this data from seabed monitors to a satellite. The satellite receives data and relays it to ground stations.

To facilitate timely data exchange and updates, the NDWC's Early Warning System Information network is linked into the information networks of ten state agencies. Those agencies include the Meteorological Department, the Department of Mineral Resources, the Naval Hydrographic Department, the Department of Disaster Prevention and Relief, the Department of Fisheries, the Royal Irrigation Department, the Department of Maritime Transport and Commerce, the Electricity Generating Authority of Thailand, the National Park, Wildlife and Plant Conservation Department, and the Pollution Control Department. The NDWC is also linked into international disaster prevention and mitigation information networks, including the Pacific Tsunami Warning Center in Hawaii, the U.S. Geological Survey, and the Japan Meteorological Agency.

In the event that the data shows a high probability of a tsunami incident occurring, a warning for high-risk areas will be issued by NDWC and transmitted simultaneously via the nationwide radio network, television network, as well as via SMS to some 20 million cellular phone users.

To alert tourists and residents of impending danger, sirens will be sounded. Public warnings in form of audio-recordings in various international languages will be broadcast from the 30-meter high warning towers. NDWC has installed 99 warning towers along the Andaman Coast. The towers are equipped with solar-powered warning systems. Solar panels are used to charge batteries that power the warning systems. In case of emergency, when electricity outages might occur, local government officials can push a button to activate sirens to warn the public to leave danger zones for appropriate evacuation sites. All warning towers were installed and completed in 2006 and a series of disaster response drills were conducted to educate local communities on how to respond to the warnings.

2.3 Village Power Applications for Tsunami Recovery in Malaysia

The tsunami that hit the islands of Penang and Langkawi was only a secondary hit, unlike the waves that crashed onto the shores of the Indian Ocean sub-continent. The total

[8] www.tatnews.org/common/print.asp?id=2978

number of deaths in Malaysia was estimated at less than one hundred, mainly Malaysian and not foreign tourists. The infrastructure on both islands remained intact. There were no problems with electricity or water supply, or with telecommunications, transportation or accessibility of towns and airports. Hotels and resorts in both Penang and Langkawi were minimally affected and were able to open for businesses only after a few days after the tsunami. Malaysia recovered quickly from the tsunami and actually diverted their efforts to assist neighboring economies in various ways.[9]

The electricity supply industry in Malaysia is dominated by three integrated utilities—Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Berhad (SESB), and Syarikat SESCO Berhad (SESCO). The one that serves Peninsular Malaysia, which was partially impacted by the tsunami, is TNB. About 100 percent of households in Peninsular Malaysia were electrified before the tsunami. Thus, village power technologies were not adopted there for new power generation projects.

The Ninth Malaysia Plan designed for the period of 2006-2010 is now underway. Regarding energy, the plan specifies that fuel sources will be diversified through greater use of renewable energy. With the goal of reducing heavy reliance on natural gas, however, the utilities' diversification of fuel sources for power generation has translated mainly to an increased use of coal. Two coal-based plants were commissioned by TNB and one by SESCO. Another source of power is hydroelectric. The Bakun hydroelectric project with an installed capacity of 2400 megawatts will be commissioned in Sarawak in 2009-2010. An expansion of the grid system is also being commissioned. The East-West Interconnection Grid in Sabah is scheduled to be completed in late 2007.[10] This grid will be integrated with the East Coast Grid and Northern Grid to transfer electricity supplies between the west and east coast of Sabah. In Sarawak, the SESCO Grid will be expanded. New Transmission lines will also be constructed to supply electricity from the Bakun project to Kemena and Balingian.

There was no report that any village power technologies were used in connection with tsunami emergency response or community reconstruction in Malaysia.

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[9] http://thanks4supporting.us/updates-on-tsunami-aftermath-in-malaysia.html

[10] Malaysian Resources Corporation Berhad, Corporate Briefing, July 2007.

Chapter 3

Obstacles to Adoption of Village Power Technologies

Many village power technologies are commercially available and could be an important part of tsunami recovery and reconstruction efforts. Technologies such as solar flashlights or portable photovoltaic (PV) systems that power shelters, radio systems, emergency telephones and repeaters, or PV panels for battery charging are useful tools that have been used frequently in disaster relief in the U.S. These village power technologies were, however, not adopted in Thailand or Malaysia, and were utilized on a limited scale in Indonesia. Village power technologies such as off-grid solar electric systems, solar hybrid with wind and/or diesel electric systems, and hydropower could have been used for reconstruction in tsunami impacted communities. These technologies have been utilized to some degree in Indonesia and Thailand. Several obstacles existed that prevented these village power technologies from being adopted to a greater extent in the tsunami recovery efforts. Direct interviews were made, and project questionnaires were sent out to authorities in Indonesia, Thailand, and Malaysia to examine why village power technologies have not been widely used for tsunami recovery and reconstruction activities in their economies. This chapter presents the findings from these interviews and questionnaires.

3.1 Obstacles to Adoption of Village Power Technologies for Disaster Relief

Village power technologies were not widely adopted for emergency responses in any of these three economies. Based on the interviews and questionnaire responses received from authorities of the three economies, the principal reason for not adopting village power technologies for disaster relief was that they were too costly, and that the governments lacked the funds required to purchase them. The government-run disaster relief agencies normally use traditional and basic rescue gear and equipment for their activities. Some relief agencies mentioned that they did not even have enough such basic rescue equipment to do their jobs and believed that more units of basic rescue gear would help them respond to emergencies more easily and efficiently.

Indonesia's Bakornas PBP, the National Disaster Relief Agency, is the main agency responsible for disaster relief and rescue in Indonesia. Bakornas PBP worked with the Indonesian military and other volunteer rescue teams to help tsunami victims. No village power applications were brought in for immediate use as they were not available or ready to be deployed by the rescue teams. To be available for immediate use, equipment such as solar flashlights or portable PV-powered systems must be kept in stock. Since the rescue agencies did not have these technologies in stock and there were no pre-arrangements to obtain them, there was no time to find suppliers or acquire such technologies for immediate use despite international donations that poured in to assist Indonesia after the tsunami incident.

It was reported that the only village power technology used for tsunami disaster relief in Indonesia was the satellite-based solar-powered public telephone system used to coordinate emergency response activities in Nangroe Aceh Darussalam, in the northern part of Sumatra. This technology was donated and used by other agencies but not by the Bakornas PBP, the main disaster relief agency.

In Thailand, the Department of Disaster Prevention and Mitigation (DDPM) is the designated agency for disaster prevention and mitigation, as well as for rehabilitation of devastated areas and assisting disaster victims. DDPM has Disaster Prevention and Mitigation Regional Centers in twelve provinces around Thailand ready for immediate emergency response. DDPM did not employ any village power technologies for tsunami related activities as none of those technologies were available for use. Village power technologies were also not used by other private volunteer groups or military rescue teams that worked in the tsunami disaster areas. Government officials from different levels at the DDPM gave different answers for why village power technologies were not employed for Thailand's tsunami emergency response. The higher-rank government officials explained that DDPM did not receive sufficient funds from the central government to buy what were perceived to be expensive village power technologies. The lower-ranked staff of DDPM who worked in the regional offices said that they did not know enough about advanced technologies that could be utilized for disaster relief, and/or did not know where to obtain them. They used whatever disaster gear and equipment was provided to them by DDPM headquarters in Bangkok.

It seems fair to say that Thai government officials at the Ministry level, who were in a position to authorize budgets for village power technologies to be used by DDPM staff for emergency response, did not fully understand these technologies and their benefits, and therefore did not see the need to provide the funds necessary to purchase them. The budget could always be prioritized to obtain these technologies if desired by authorities. Because before the 2004 tsunami, Thailand had rarely experienced any natural disasters even at a small scale – not to mention such a large-scale, high-impact disaster, the DDPM had not seen the importance of having any advanced technologies that could be useful for emergency tasks. The DDPM officials said that they would seriously consider recommendations from APEC to prepare better for future disasters by employing village power technology.

3.2 Obstacles to Adoption of Village Power Technologies for Community Reconstruction

The main reconstruction activities after the tsunami were to restore power, transportation and communication systems, and to rebuild shelters and communities. In Thailand, the devastated areas were almost totally electrified by grid connections. Only small parts of the damaged areas, such as those on small islands off the coast and a few remote houses far from the electricity grids, were not electrified. The tsunami did not damage power generation or regional transmission systems in the affected areas. Only some local distribution lines were disrupted. After the tsunami, staff at the local offices of the Provincial Electricity Authorities (PEA) fixed the damages and power was restored in a few days. During those few days of power outages, small diesel generators were brought in to provide power for doctors and emergency crews. A doctor from the Royal Thai

Navy who worked at the site said that these generators were very noisy and disturbing, and he wished that the Navy had had portable solar systems to use instead of diesel generators. The portable solar systems could also have helped provide lights to tsunami victims at the shelters. However, none were available for deployment. The PEA's provincial managers in all six tsunami-affected provinces who were interviewed all said that the PEA had enough crews and could fix existing power systems very quickly when needed, and thus there was no need to bring in a village power technology like portable solar systems. When asked if the PEA would consider purchasing portable solar systems to provide electricity for emergency shelters as future natural disasters could be more serious and could damage PEA's main power systems – and require a longer time to fix – managers responded that, in their opinion, village power technologies like portable solar systems were too costly and they were not sure if they would work well enough to be worth the PEA's investment. It should be noted, however, that PEA provincial offices do not set their own policies. Decisions on purchasing new technologies or implementing new projects are made by PEA headquarters in Bangkok.

Shelter and community rehabilitation in Thailand were conducted by the Department of Public Works and Town & Country Planning, the principal Thai government agency responsible for reconstruction after the tsunami, as well as by various charity groups, corporate donors, and military teams (the Royal Thai Army and the Royal Thai Navy). The reconstruction focused on rebuilding new homes for victims as quickly as possible so victims could go back to their normal lives. As all areas were electrified, there was no need to adopt village power technologies, as those technologies would not be cost effective in comparison to grid electricity. Technology like solar-powered water heaters is not used commonly in Thailand. Thailand has a year-round tropical climate so hot water for showers is a luxury and is only used in high-income houses.

In some tsunami-affected areas, water supply systems and community and household wells, which were sources of drinking water and clean water for household uses, were damaged and infiltrated by seawater and contaminated water from damaged septic tanks and toilets. Truckloads of bottled water were distributed for villagers during emergency periods. To provide clean drinking water during the post-disaster rebuilding period, the Thai government leased thousands of water purification units from a local company. These were distributed at no charge to each community. These units were powered by grid electricity. Solar-powered water purification systems would not be cost-effective in places where grid electricity is available.

About 40 percent of Aceh and Nias, the tsunami damaged areas in Indonesia, were unelectrified. The Aceh-Nias Rehabilitation and Reconstruction Agency (or BRR) was established after the tsunami to take responsibility for coordinating and overseeing the rehabilitation and reconstruction in tsunami-affected areas. While tsunami reconstruction activities in Thailand and Malaysia are now completed, Indonesia is still rebuilding and rehabilitating its damaged areas as the tsunami impacts there were much more massive than those in the other two economies. To date, BRR itself has not implemented any projects using village power technologies (although micro-hydro is on its list to be considered for village electrification in Peusangan in Aceh). The reasons given by BRR authorities were that it was a combination of (1) no funds available for the purchase of village power technologies, (2) no knowledge about the technologies, and (3) no knowledge of where to purchase the technologies.

Although the government-run agency might not have utilized village power technologies for reconstruction and rehabilitation of communities, some village power projects were launched in Indonesia after the tsunami by the private sector and local NGOs. The village power technologies utilized included off-grid solar systems, solar and wind hybrid systems, solar-powered tsunami early warning systems, and micro-hydropower projects. Lack of expertise in utilizing these technologies was the other reason why village power technologies were not adopted more for tsunami reconstruction in Indonesia. The 40 kW Krueng Kala micro-hydropower project in Aceh Besar District was built after the tsunami using the Corporate Social Responsibility Fund of PT Coca Cola Indonesia. The project faced a central problem of finding local people with the technical skills needed to operate the plant. The authorities reported that it took a significant amount of time to select people with some technical background and train them to work at the facility. In addition to technical difficulties, other problems with the project included the local community's traumatic mental condition, which impacted their ability to work, and high costs of labor and construction that had to be supplied from outside Aceh. The use of solar home systems in community reconstruction was limited by high cost, as these systems mostly have to be imported. In addition, because they lack the expertise, local people do not tend to maintain these facilities adequately.

Malaysia had the least damage from the tsunami when compared to Indonesia and Thailand. Businesses in Penang and Langkawi, the areas hit by the tsunami, were open a few days after the tsunami. There was no report of any village power technologies being used for emergency response. Electric utilities, water supplies and telecommunications had little damage. About 100 percent of households in Peninsular Malaysia, which the tsunami partially affected, were electrified before the tsunami, and the power system suffered little damage. Village power technologies were thus not adopted for new power generation projects in Malaysia.

Chapter 4

Village Power Programs and Lessons Learned

This chapter discusses existing village power programs and lessons that could be learned from those programs. The chapter examines village power programs in Indonesia, Thailand, and Malaysia—the three studied economies—and the village power programs in Kiribati and the Marshall Islands. Although not APEC members, the village power programs in these two Pacific Islands provide valuable lessons that will be useful to APEC economies. The chapter begins by reviewing lessons learned and best practices from village power programs discussed at the APEC workshop in New Zealand in 2004.

4.1 APEC 21st Century Renewable Energy Development Initiative (Collaborative I): Technical Workshop to Support Village Power Applications

In November 2004, APEC held a village power workshop in Canterbury, New Zealand called APEC 21st Century Renewable Energy Development Initiative (Collaborative I): Technical Workshop to Support Village Power Applications.[11] The purpose of the workshop was (1) to explore renewable energy technology options and solutions for village power applications; (2) to share lessons learned, best practices, and experiences in the use of renewable energy for village power applications; and (3) to explore establishment of an APEC regional network of village power champions and proponents. The workshop discussed topics such as lessons learned and best practices of village power programs in APEC, productive uses for renewable energy, technology updates, tools for evaluating village power options, and financing for village power projects and programs in APEC economies. The lessons learned and best practices from village power programs in APEC member economies presented at that workshop are reviewed in this section.

National Township Electrification Program in China[12]

Over 97 percent of China's population of 1.1 billion people has access to electricity services. However, there remain over 29,000 villages with some 60 million people without electric services. These villages are mainly in regions where extension of the grid is technically difficult and financially prohibitive. China initiated the National Township Electrification Program in 2002. The program focused on the use of renewable energy systems to electrify over 1,000 villages where township governments were located. Over 18 megawatt peak (MWp) of PV were installed in seven provinces under this program, with individual PV systems up to 150 kilowatt peak (kWp) in size. Other systems being used include PV power systems, hybrid systems of wind/PV, wind/diesel,

[11] www.egnret.ewg.apec.org

[12] Song Yanqin, "China's Township Electrification Program and Other Government Rural Energy Initiatives," Center for Renewable Energy Development, China; and Charlie Dou, "Prospects for and Barriers to Renewable Energy-Based Rural Electrification in Developing Countries: Experience and Lessons Learned from the Field in China," Bergey Windpower, US/China.

and wind/PV/diesel, and micro- and mini-hydro plants. The use of renewable energy for village power applications in China presents special challenges, including the following:

- Solar and wind resource surveys are needed to facilitate optimal system sizing and design.
- Village system ownership is often unclear where there are government investments and donor subsidies as well as local village participation.
- Government-assigned contracts to rural energy service companies for system management have not been particularly successful.
- Given the expectation in some rural communities that electricity should be provided at no charge, it is very difficult to collect revenues for electricity sales.
- Maintenance can be complicated, and qualified technicians are often not available.
- Sustainability remains a problem given the upfront capital costs of the renewable-based energy systems, the need for high-quality batteries and mechanisms for ensuring their replacement (e.g., sinking fund), retention of trained staff (who may find more attractive jobs after they received renewable-energy system operations training), and the need for effective business models for sustainable operations. The government-funded projects often concentrate on social welfare objectives without explicitly supporting enterprise and income development. To make renewable energy-based village power systems sustainable, the focus of the systems should be on economic productivity as well as on social development.
- Training of owners and operators of renewable energy systems is inadequate and needs to be expanded, and
- System acceptance is an issue in some places.

Renewable Energy-Based Rural Electrification in Vietnam[13]

About 82 percent of households in Vietnam are electrified, of which 99 percent are powered by grid connection. The national rural electrification goal includes electrifying 90 percent of households by the year 2010 with good quality electricity services. Vietnam's renewable energy resources include hydropower, wind, solar, biomass, geothermal, tidal, and wave. The potential of these renewable energy sources is, however, not yet well determined. The major barriers to the development of renewable energy resources in Viet Nam include (1) inadequate policy and regulatory framework to encourage renewable energy-based electricity, (2) inadequate awareness of renewable energy technologies, costs, and performance, (3) lack of commercial businesses in Vietnam that can provide renewable electricity equipment and services, and (4) lack of financial sources.

In 2001, Vietnam developed a Renewable Energy Action Plan, with assistance from the Energy Sector Management Assistance Program (ESMAP) of the World Bank. It is a ten-year large-scale renewable energy development program focusing on renewable

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[13] Pham Thuy Dung, "Renewable Energy-Based Rural Electrification in Viet Nam," Energy & Petroleum Department, Ministry of Industry, Vietnam.

electrification for rural, remote and mountain areas. The plan is being implemented between 2001 and 2010 in two phases—a five year capacity building phase, and a five year implementation phase. The plan is to use renewable energy for energy applications ranging from PV and pico-hydro systems for households, mini-hydropower systems for community grids, and grid-connected mini-hydro and biomass power systems. The plan gives priority to providing energy services in poorer isolated communities and villages and is built on six strategies that include: (1) using renewable electricity when it is the least costly option and economically viable; (2) renewable electricity will be supplied on a commercial basis to all types of businesses, including a variety of private and public sector companies, cooperatives, and NGOs; (3) having communities, individual consumers, and investors contribute to, and participate in, the program to share costs and benefits; (4) having the government help create an encouraging market environment by issuing policies and establishing the legislation and regulation to support commercial development; (5) increasing access to long-term credit to improve the financial viability of businesses and affordability of services; and (6) providing limited grant assistance in recognition of the social and environmental benefits; this grant assistance will be used carefully. For off-grid facilities targeted at poorer communities, capital cost subsidies will be considered.[14]

Renewable Energy Use in Mexico[15]

Mexico has been developing its renewable energy resources for several decades, with 838 MWe of geothermal capacity currently online, 14 MWp of PV installations, 40 MWe of mini-hydro, 17 MW of biogas, and 2 MWe of wind electric power. Mini-hydro resources are conservatively estimated at 400 MWe. Mexico also has high solar resources, and solar installations for thermal and electricity applications are limited only by markets and economics.

The barriers to greater use of renewable energy and village power technologies in Mexico include (1) high initial costs of the technologies, (2) poor information about the resources, (3) subsidies to end-users (mainly in residential and agricultural sectors), (4) lack of technical expertise for project development, (5) no incentives, and (6) large transaction costs making small projects uneconomical.

The Bushlight Program in Australia[16]

Australia conducted a renewable energy market survey with field visits to 88 indigenous communities to identify problems with renewable energy installations. The survey

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[14] Renewable Energy for Development: The Role of the World Bank Group, World Bank (June 2004), see www.worldbank.org/vn.

[15] Dr. Diego Arjona, "Intelligent Energy Use: Renewable Energy Markets," National Commission for Energy Conservation (CONAE), Mexico.

[16] Geoff Stapleton, "The Australian Bushlight Program," Global Sustainable Energy Solutions Pty Ltd, Australia.

showed that only 64 percent of the installed renewable energy systems were operational. The survey also revealed that only 40 percent of people were satisfied with their renewable energy systems due to problems with system reliability and difficulties in maintaining the systems in an operational state. The problems uncovered by the surveys included: (1) lack of regular maintenance, (2) complex, non-standard technology, (3) lack of electricity demand management, (4) lack of trained community members and staff, and (5) insufficient technical support.

The Bushlight program was established in 2002 to provide improved livelihood options for indigenous people in Northern Australia by increasing access to sustainable renewable energy services. The program was designed to address issues regarding problems with renewable energy installations in indigenous communities as revealed by the Australian renewable energy market survey. Bushlight was a four-year project, conducted from 2002 to 2006. The program was a joint venture between the Centre for Appropriate Technology (CAT) and the Australian Cooperative Research Centre for Renewable Energy (ACRE) with financial support of AUD 8.4 million from the Australian Greenhouse Office through the Aboriginal and Torres Strait Islander Commission. The program's objectives were to improve renewable energy system designs (for household systems, community systems, and hybrid systems), to increase community capacity to manage energy services, and to improve the support network. The program included extensive interaction with local communities from system designs, to training on system operation, maintenance, and proper utilization.

Off-Grid Electrification in the Philippines[17]

The Philippines has topography that is composed of thousands of small islands and mountainous regions. The government has provided varying degrees of electricity services to 91 percent of the almost 42,000 communities. The Philippine Rural Electrification Program, implemented through the national Department of Energy, is composed of an on-grid electrification program (power distribution development) and an off-grid (or Missionary) Electrification Development Plan. Typical centralized systems in the Philippines are mini-grids of small diesel generators or wind/diesel hybrid systems. Centralized systems are normally for coastal and island communities that are compact with clusters of 200 households or more. These are less poor communities where residents are able to purchase AC electricity services.

The Small Power Utilities Group (SPUG) is responsible for providing power in missionary areas that are not connected to the national transmission grids and to those that cannot be serviced by distribution utilities. These are typically sparsely populated communities with 150 households or less, with an economic status ranging from less poor to poorest. Solar PV battery charging stations are provided to the poorest communities, and solar home systems are provided to less poor communities. As of 2003, SPUG

[17] Rene Barruela, "Missionary Electrification in the Philippines," Small Power Utilities Group, National Power Corporation, the Philippines.

completed the solar PV battery charging stations, with total capacity of 81 kWp, which serve 5,400 households in 259 villages.

Rural Electrification in Chile[18]

More than 1,500 remote power systems have been installed in Chile, using a mix of renewable and fossil fuel power options. Chile's rural electrification coverage has grown from 55 percent in 1992 to 79.5 percent in 2001. About 20 percent of the rural population still lacks access to electricity services. The national goal was to reach 90 percent rural electrification across all regions by 2005. Chile's national energy commission (CNE), the United Nations Development Program (UNDP), and the Global Environment Facility (GEF) launched a project in 2001 aiming at removing the barriers to rural electrification throughout Chile. The five-year, US$ 32.4 million project aimed to strengthen and better direct existing policies so that the present 78 percent rural electrification rate was increased to 90 percent by 2005. The funds for the project came from GEF (US$ 6 million), Chile's government (US$ 17.2 million), the private sector (US$ 7.6 million), and power-users (US$ 1.5 million).

The project included the expansion of a diesel/wind hybrid system from Tac island to another 32 islands in the Chiloe archipelago, the implementation of solar solutions to benefit up to 5,000 families in the north and center-south of Chile, and other more disperse projects such as small-scale hydro projects in the northern desert, wind projects on Robinson Crusoe island, and biomass and geothermal projects at other locations.

The project also addressed issues learned from the Isla Tac project, including:

- Electricity demand was 50 percent underestimated,
- Local mini-grid losses were greater than 20 percent,
- The technology was not amenable to modular expansion or growth in capacity,
- The tariff was inappropriately low, and
- The operator was a utility company that lacked appropriate experience in operating small or mini-grids.

The lessons learned from rural electrification in Chile were that the combination of commercially productive applications, high-quality equipment, a skilled and experienced technical staff, and provision of energy services rather than just equipment, was the most appropriate way to provide reliable energy services to communities and commercial/industrial facilities beyond the reach of the power grid.

4.2 Village Power Programs in Indonesia

Various village power applications are being utilized in Indonesia. Three Indonesian government agencies have been continuously implementing activities related to rural

[18] Nelson Stevens, "Wireless Energy - A Small Business Perspective in Rural Electrification," Wireless Energy Chile, Ltda, Chile.

electrification. Those include the Directorate of Mining and Energy, the Agency for the Assessment and Application of Technology, and the Directorate General of Electricity and Energy Utilization. Indonesia has installed over 1,000 of solar home systems, about 40 micro-hydropower stations, and some hybrid solar and wind systems. A PV rural electrification program and micro-hydropower are discussed below to show valuable lessons learned from these programs.

PV Rural Electrification Programs in Indonesia

The first solar home systems (SHS) pilot project in Indonesia was conducted in the village of Sukatani, West Java, in 1989, where 85 SHS and 15 solar powered streetlights were installed under a Dutch-Indonesian cooperation program, followed by the 500 SHS installed in Lebak district in West Java in 1990.[19] This pilot project led to a major government project, the BANPRES project in 1991, and a development of a larger-scale SHS program called "Fifty Mega Watt Peak (50MWp) Photovoltaic Rural Electrification" in June 1997. The program details and lessons learned are discussed below.

BANPRES Project [20]

The BANPRES Project (the Presidential Assistance Project) started in 1991 with funding from a presidential grant through the Development Budget (DIP). The goal of the project was to test the technical and social viability of PV for large-scale household electrification programs as a means to provide cost-effective electricity services to several million rural Indonesian households that were unlikely to receive grid electricity for at least ten years.

The project was led by the Agency for the Assessment and Application of Technology (BPPT), which was responsible for all technical aspects of the project including specifying and qualifying products, field testing, and monitoring. A Steering Committee was set up to oversee the project, chaired by BPPT and consisting of key government agencies, including the Directorate General for Electricity and Energy Development, Ministry of Cooperatives, Ministry of Transmigration, PLN (a public utility), Bank Indonesia, and Bank Rakyat Indonesia (BRI). The BANPRES project relied on village cooperatives (Koperasi Unit Desa or KUD) to administer it at the village level. The KUD

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[19] E. Kantosa Fitriana, A. Sudradjat, J. Kuhmann, K. Preiser, and P. Schweizer-Ries, "On the Way From Sukatani to the 50 MW Programme: A Socio-Technical Analysis of Solar Home Systems in Indonesia," Undated, see www.ise.fraunhofer.de/english/fields/field3/mb1/materialien/On%20the%20way%20from%20Sukatani%20to%20the%2050%20MW%20programme%20-%20A%20socio-technical%20analysis%20of%20solar%20home%20systems.pdf

[20] Anil Cabraal, Mac Cosgrove-Davies, and Loretta Schaeffer, "ANNEX 1: ASTAE Case Studies in PV Household Electrification," in Best Practices for Photovoltaic Household Electrification Programs: Lessons from Experiences in Selected Countries, World Bank Technical Paper 324, Asia Technical Department Series, August 1996, see www.worldbank.org/astae/pvpdf/annex1.pdf

duties included collecting fees from users, providing maintenance services, and enforcing disconnects for payment defaults. A revolving fund was set up for the project at the BRI with the presidential grant. BRI was selected to be the project's financial institution because of its widespread presence in rural areas.

Several criteria were used to select villages for the project. The criteria included the desire for electricity, the location relative to the KUD, grid electrification plans, and capacity of householders to pay for the down payment and monthly installments. Residents in a selected village could receive BANPRES systems if they were KUD members, had ability to pay, and were willing to sign a lease-purchase agreement with the KUD. The KUD would contract an SHS supplier to install the systems for qualified residents. The systems are required to meet the BPPT's specifications. The SHS installed consisted of a 45 to 48 Wp photovoltaic panel, support structure, two fluorescent tube lights, switches, a 12-VDC outlet, wiring, an automotive battery, and a battery control unit. The system could generate 145 Wh/day in a day with 6 hours of bright sun, and could provide 7-8 hours of lighting when operating both lights, or provide 5 hours of lighting and 5 hours of television.

The financial arrangement in the project was that KUD collected a 50,000 rupiah down payment and a 7,500 rupiah monthly payment per household, for 10 years at zero interest. The KUD retained 500 rupiah per month per system to cover its costs and transferred the remainder (7,000 rupiah) to the BANPRES revolving fund account at BRI. Each KUD employed two maintenance and repair technicians. KUD was responsible for regular inspection of the SHS and was required to provide the provincial government with a semi-annual written report on the project's progress.

The BANPRES project laid good groundwork for SHS adoption in Indonesia. The project was relatively successful. There were no reports of major technical problems with the solar systems or their major components. The suppliers offered warranty services and in generally abided by warranty terms and promptly replaced detective equipment when claims were placed. One reported problem was that most users were not fully satisfied with the level of energy the systems provided. As only two fluorescent lamps were allowed, users with more than two rooms used kerosene to provide light in additional rooms. If they wanted to watch TV, they had to keep lights off. Many users used kerosene, dry cell batteries, and diesel generators in parallel with their SHS. Most users bypassed the charge controllers when they realized that the controllers restricted the lighting duration. Many fully discharged the battery thereby damaging it. Posters were used to educate people in maintenance and proper operation of the system. Yet this problem existed throughout the project.

The BANPRES project was implemented in 15 Indonesian provinces and resulted in the installation of more than 3,500 SHS.

Fifty Megawatt Peak (50 MWp) Photovoltaic Rural Electrification[21]

The 50 MWp program was the world's largest decentralized rural electrification program based on PV power. The Indonesian government launched this program in 1997 to achieve the long-term goal of 100 percent rural electrification at the end of Five Year Development Plan VII (1999-2004). The target of the project was to electrify one million households in ten years using SHS with total power of 50 MWp. The program was carried out in stages with support from various foreign donors. The strategy was to have government-based programs targeted at the higher-cost remote areas and to serve the poorer segments of the population, and to have commercially-based, private sector led programs for the relatively more affluent segments of population.

The 50 MWp program was based on experience gained from the BANPRES project. It emphasized the involvement of KUD working with a team of government agencies led by BPPT. A revolving fund was set up with funds from donors and the government and was administered by KUD. KUD was responsible for collecting payments from buyers, and provided spare parts and maintenance services.

The SHS specifications recommended by BPPT were for an individual system consisting of:

- 1 photovoltaic module with a minimum of 50 Wp that would be installed on a roof or ground pole where it was free from shadows,
- 1 battery charge regulator to protect the battery from excessive charging and discharging, and to control the power to the load,
- 1 storage battery to store electricity for at least 3 days,
- 1 battery box to protect the battery from the weather and for safety,
- 3 DC fluorescent lamps, 6W each, and
- 1 set of installation materials, which consisted of cable, 3 switches, 1 DC outlet, and a connector.

The government set a number of criteria that a village had to satisfy in order to receive aid from the program. Those criteria included:

1. A remote location, far from the center of town,
2. Lack of available grid connection for at least the next ten years,
3. Problems with adequate electricity especially for lighting and information flow,
4. Sufficient solar energy resource potential to satisfy technical requirements,
5. Have KUD or a similar organization,
6. Residents able to pay for the hardware according to the agreement, and
7. Participation recommendation from local government (PEMDA).

[21] Agus Salim Dasuki and Martin Djamin, "Fifty Mega Watt Peak (50 MWp) Photovoltaic Rural Electrification in Indonesia," Photovoltaic Energy Conversion, 1994, Conference Record of the Twenty Fourth, IEEE Photovoltaic Specialist Conference, Waikaloa, Hawaii, USA. IEEE Publication, December 1994, Volume: 2, pps 2379-2382.

Potential consumers were classified into three segments for financing purposes.[22] Segment 1 included the consumers in underdeveloped areas and transmigration sites. Segment 2 included consumers in more developed areas with the ability to buy SHS with a down payment and up to 10 years of monthly installments. Segment 3 targeted consumers with the most developed economic status who had the ability to buy SHS with 1 to 3 years of installment payments.

Three financial schemes were designed for the three segments of consumers. Financial Scheme 1 was designed for consumers in Segment 1 in which the government would pay all costs that covered the PV system, installation fee, transportation costs to the site, site surveys, and training to operators and consumers. Segment 1 consumers would pay a monthly maintenance fee for operational costs, and for battery replacement. Financial Scheme 2 was for Segment 2 consumers. This required consumers to pay for their own PV systems (with ten-year lease-purchase contracts) and pay a monthly maintenance fee. The government would pay for installation, and all other costs. Financial Scheme 3 was for Segment 3 consumers who would pay for all costs by putting down a larger payment (between 20 to 30 percent of the total cost) and who would use a lease-purchase contract to pay monthly installments over three years. However, in Financial Scheme 3, the government would provide a subsidy for a fraction of the whole system price. In Financial Schemes 1 and 2, consumers bought SHS through a revolving fund supported by donor and government assistance, and administered by KUD. In Financial Scheme 3, consumers bought SHS directly from SHS dealers. The dealers identified potential and eligible customers, were responsible for procurement of components, installation and maintenance, and determined consumers' payment terms.

There are three major donors to this 50 MWp program, including the Australian Agency for International Development (AusAid), the Bavarian government of Germany, and the World Bank/Global Environmental Facility (WB/GEF).[23] AusAid[24] assisted the 50 MWp program with a $30 million soft loan to Indonesia to establish the revolving credit funds for SHS, for equipment testing by BPPT, training, and some partial grants for households in the transmigration areas. The goal was to install 36,000 SHS in nine eastern Indonesian provinces, including Southeast Sulawesi, Central Sulawesi, North Sulawesi, West Nusa Tenggara, East Nusa Tenggara, East Timor, Maluku, Central Kalimantan, and Irian Jaya, during the period from 1997 to 1999. The private sector involved in the project was Altari, PT LEN that provided installation and training for KUD. Altari, PT LEN was part of a consortium with Solarex (Australia) the company that manufactured

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[22] Dr. Martin Djamin, Ir. Ahmad Yusak Lubis, and Dr. Agus Salim Dasuki, "Financial Scheme and Experience on Application of Solar Home Systems in Indonesia," Agency for Assessment and Application of Technology, Indonesia, see www.oja-services.nl/iea-pvps/conference/downloads/s36_djamin.pdf

[23] The other projects in this 50 MWp program included the 1000 SHS and 1 PV hybrid system supported by the E7 and the 1300 households in 4 PV hybrid systems with cooperation from a French program.

[24] National Renewable Energy Laboratory's Renewables for Sustainable Village Power, see www.nrel.gov/villagepower/asp/projectlist.asp

the balance of systems. The PV modules used in the project were imported, but other components were locally produced. All systems were required to meet a certain standard established by BPPT and to be certified to qualify for the program. The power loads per household included 3 lights, a radio, and a black-and-white TV. The size of each household solar panel was 50 Wp.

The Bavarian Ministry for Economic Affairs, Transport and Technology (of Germany) worked with BPPT in the Bavarian-Indonesian Governments Solar Project (BIG-SOL project). The Bavarian government contributed 20 million DM as a matching grant to the 20 million DM from the Indonesian government and Indonesian private sector. The project consisted of PV/diesel hybrid systems, large solar home systems, and solar systems for productive uses installed in the District of Lamongan, East Java Province. The project emphasized productive use for income generation in rural areas. The solar systems for productive uses included solar boat systems, incubators for chickens, rural telephone, and chicken barn lightings. The project aimed to install 30,000 individual PV systems and 300 centralized systems.

The World Bank (WB) and the Global Environmental Facility (GEF) assisted Indonesia in meeting its 50 MWp solar goal by providing a US$20 million IBRD loan (from the International Bank for Reconstruction and Development) and a US$24 million grant (from GEF) to the program in 1997.[25] The WB/GEF project focused on capacity building and participation of the private sector in advancing renewable energy commercialization. While the AusAid and BIG-SOL project supported Financial Schemes 1 and 2, which were demonstration schemes and represented most SHS installed in the program, the WB/GEF project supported Financial Scheme 3, which was a semi-commercial scheme.

The WB/GEF project aimed to provide electricity to one million people in three provinces—Lampung (Sumatra), West Java, and South Sulawesi—through the sale and installation of 200,000 SHS units. The customers were the Segment 3 group who would pay for their own SHS. The project, however, contributed a subsidy of US$2 per Wp to these consumers. In this project, the sales, installations, and maintenance of SHS units were undertaken by SHS dealers. The SHS dealers set monthly installment terms that would enable consumers to pay for their systems. The project established a solar credit system through four Indonesian commercial banks. These participating banks (PB) would provide loans to SHS dealers for up to five years at commercial interest rates. The PB would then re-finance 80 percent of the loan extended to SHS dealers through the Indonesian government under the IBRD credits. To lower the system prices for consumers to a level that they could be paid back in affordable monthly payments over no more than 3 to 4 years, the GEF grant would buy down to SHS dealers for each SHS unit sold and installed (US$75 per unit installed in Java, and US$125 per unit installed in Lampung and South Sulawesi).

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[25] Indonesia-Solar Home Systems Project, The World Bank Report No: 29153, Implementation Completion Report (TF-28488) on A GEF Grant in the Amount of SDR 16.8 Million to the Republic of Indonesia for the Solar Home Systems Projects, June 21, 2004.

The East Asia financial crisis in late 1997 significantly impacted the WB/GEF project. It caused an economic crisis and currency depreciation in Indonesia that resulted in a weak business environment, and decreased ability of consumers to afford SHS. Beginning in 1998, the minimum size of SHS units eligible for a grant was reduced from 50 Wp to 10Wp to counter the reduced affordability to consumers. In 2000, the basis of the grant to dealers was changed from a per unit basis to a per unit of power output (per Wp) basis so as to allow larger systems be eligible for larger grants. The grant rate was US$2 per Wp for systems, 10 Wp and above, for systems sold in any market areas. In 2001, the SHS sales target in the project was changed from 200,000 units to 70,000 units. The IBRD loan was finally closed in January 2001 (earlier than the original schedule of April 2002). This change was made because less than US$0.1 million of the US$20 million loan had been used by December 2000 due to lack of demand for the loan from the dealers, and because PBs were not able to offer new credits to the dealers following the banking sector crisis. The grant from GEF was then reduced from US$24 million to US$11 million in January 2001, and to $5.2 million in April 2003 because of diminishing sale prospects of SHS. The grant was closed in December 31, 2003. At the end of the project, a total of 8,054 SHS units, serving about 35,000 people had been installed—well below the new 2001 target of 70,000 SHS units serving 300,000 people.

Many lessons could be learned from the PV rural electrification programs in Indonesia. One problem reported from the BANPRES project was that the project lacked effective communication and a modern information management system. Thus the problems at the sites (i.e., equipment problems, late payment, etc.) could not reach proper authorities in a timely manner. The BANPRES systems were difficult to monitor due to budget constraints. As the budget allowed only two site visits per year, it was difficult to learn about the systems' problems and difficult to fix them. The AusAid and BIG-SOL projects capitalized on that lesson. For the AusAid and BIG-SOL projects, BPPT developed the Photovoltaic Rural Electrification Management Information System Network (MIS) to support a day-to-day photovoltaic management operation, to provide a reporting system to the photovoltaic management, to improve the quality of technical management, financial management and communication, and to improve the after-sales service. The MIS consisted of three subsystems—Central Management Information System (located at program management headquarters), District Management Information Systems (located in each district), and Management Information System Service Centers (located in each sub-district unit) that may include several villages located at convenient distances. The communication network between the Central MIS and the District MIS was established using telephones and modems, and linked to personal computer or workstations. The communication network between District MIS and MIS Service Center at each sub-district was made manually by filing information at periodic intervals on diskettes at each sub-district and transferring the diskettes between District MIS.

Local project management capability contributed to a project's success or failure. The BANPRES project encountered many problems with KUD management. For example, KUD did not keep enough spare parts for system maintenance and replacement. This led to long waits for repair. KUD also did not practice consistent bookkeeping and fee collections resulting in different fee payments and low collection rates. During BANPRES, the payments were not standardized, and some people received their systems for free. Different monthly fees among consumers led to jealousy and resentment. In addition, KUDs were not able to collect all fees. The fee collection rate in the BANPRES project in 1993 was only 60 percent. KUDs attributed the fee collection problem to seasonal income patterns and users' short-term financial problems that prevented them from being able to pay. In many cases, however, the KUDs could not force users to comply with their agreements since many KUDs did not always adhere to their contractual obligations and handled disconnects for nonpayment differently for different users. Once users learned that disconnects were not really going to be carried out, payment rates fell. In the AusAid and BIG-SOL projects, the implementation team of BPPT, KUD and local governments worked together to standardize the payment scheme, manuals, and system management.

Since BANPRES, BPPT worked with local manufactures to improve design and quality of all balance-of-system components. In the AusAid and BIG-SOL projects, at the early stage of the program, the solar modules used were imported, but all other components were produced domestically. The program thus demonstrated active local industry involvement. Later on, solar modules were manufactured by companies in Indonesia. For the WB/GEF project, although the actual sales of SHS fell short of the target and the goal of developing a large-scale market for SHS in Indonesia, the project helped facilitate participation of the private sector in advancing renewable energy commercialization. The number of dealers increased from one at the end of 2000 to six by the end of the project in 2003. In addition, the project encouraged local Indonesian firms to manufacture "balance of system" components for SHS (other components besides PV panels), have them tested initially on a grant-subsidized basis, and later on a commercial basis, to check product quality, and to arrange for technical support from international organizations to improve their quality. The two companies that received assistance with component designs and testing are now exporting system components.

The WB/GEF project contributed to strengthening local institutions and to local capacity building. The project developed SHS national quality standards, certification procedures, and a testing facility (the Photovoltaic Component Test Laboratory) with ISO 25 accreditation received in June 2001, and helped strengthen BPPT's capabilities to certify SHS by carrying out system and product testing, and by monitoring systems in the field. In the WB/GEF project, the Project Support Group (PSG) was established to monitor the actual performance of SHS, audit sales data for GEF grant release, and to provide capacity building and technical assistance to SHS dealers/suppliers, end-users, and participating banks. These activities all contributed to institutional strengthening. PSG trained more than 479 staff in the rural distribution networks of the participating companies, and familiarized the participating banks with the SHS technology, and trained them to handle loans for SHS vendors and rural customers.

The WB/GEF report also identified other lessons learned from their SHS project. These included:

- A satisfactory business environment is important for the success of a market-based development project.
- Market-based projects should allow companies to adjust product lines and business models in response to changing market conditions.
- As market entry costs are high in remote rural areas, cost-shared and performance based grants help provide incentives for dealers to enter the retail market, assist them in developing distribution operations, reduce their risks, and improve their cash flow, while helping to make the products more affordable to consumers.
- Profitability of companies is as an important factor as product affordability and consumers' willingness to pay, and should be taken into consideration in project design and in setting grant levels.
- Performance based grants in retail markets should not remain at the same level throughout the project, but should be scaled down to prepare companies for transition to a fully commercial operation at the end of the project.
- A strong consumer audit program and transparent grant releases are important. An audit program will ensure compliance with consumer protection requirements and assure fair competition among the suppliers. Transparent release of grant funds will minimize companies' time and transaction costs, minimize opportunities for corruption, and encourage dealers to focus their learning and marketing efforts on rural customers, rather than on processing paperwork for grant payments.
- Support to financial institutions that finance dealers, including providing them with information about dealers and sales opportunities in remote rural areas, helps reduce the financial institutions' transaction costs, and thus helps lower barriers to financing SHS dealers.
- The institutional market (i.e., health, education, and community-based institutions) should be targeted in an integrated way with the rural household market to expand sales and spread the development benefits to families who may not be able to afford an individual SHS unit.
- A market-based approach (i.e., competitive arrangement and community driven approaches) should also be developed for highly subsidized SHS programs to promote market competition after the program is completed.
- A well designed socio-economic survey mechanism should be built into the project to assess the development impact.

Mini-hydropower Project in Indonesia[26]

Indonesia has abundant hydropower resources that can be used to supply electricity to remote rural areas. The mini-hydro potential in Indonesia is estimated at 500 MW, of which only 21 MW has been exploited. PLN, the Indonesian national electricity utility, has a limited capacity with which to fulfill power requirements especially in rural areas where it is often economically unfeasible to extend high and medium voltage lines. Therefore, hydropower provides an alternative option for rural electrification in

[26] See www.entec.co.id/

Indonesia. As the energy policy in Indonesia was to cut energy subsidies, the competitiveness of hydropower has been increased.

The Mini Hydropower Project (MHPP) started in 1991. MHPP was a community mini-hydro project that was part of the KDP (Kacamatan Development Program). It was a cooperation project between the Directorate General of Electricity & Energy Utilization within the Indonesian Ministry of Energy and Mineral Resources, and German Technical Cooperation (GTZ) on behalf of German Government. MHPP focused on the development of local expertise in planning, constructing, operating, and managing mini hydropower schemes throughout Indonesia. ENTEC, a Swiss consulting company, was commissioned to implement the German contribution.

The MHPP project was implemented in different phases. The first phase, which was implemented between 1991 and 1996, focused on the introduction of MHPP technology to local institutions and individuals active in mini-hydro project development. The second phase, implemented between 1999 and 2002, broadened the scope of the project to include a policy dialogue, to encompass commercial and larger scale projects, and improve operation and management practices. The third phase, implemented between 2002 and 2005, continued to provide technical support and know-how to the MHPP equipment suppliers and contractors, facilitating independent implementation of these projects.

The MHPP training was on going throughout the project with joint cooperation between the private sector and educational institutes. For example, a six day "on-the-job" training course was offered to students from the postgraduate mini-hydropower course at University Gajah Mada, Yogya in April 2004. The course provided participants with a blend of theory and practical hands-on experience. The training covered manufacturing of "pico" propeller turbines, installation and testing of the equipment, and post operation productive end-use applications. The course format comprised three groups: fabrication and machining, casting, and general theory.[27]

Several lessons can be learned from the MHPP project. The project had a comprehensive approach as it aimed to utilize abundantly available and local renewable energy resources to provide electricity to remote rural areas, as well as to support economic development and improve welfare at village level.

The third phase focused on four objectives: transfer of know-how, facilitating access to funding, support of income generating end-uses, and encouraging networking and experience sharing. These objectives are important elements in promoting the success and sustainability of any renewable energy projects.

Another exemplary feature of the MHPP project in Indonesia was that, as a standard practice, it offered extended technology solutions to facilitate income-generating uses of energy. In remote areas where investment costs are comparatively high, efficient

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[27] "Mini Hydro Power Project Newsletter," 8th edition, April 2004 (www.entec.co.id/news.htm).

utilization of generated power is particularly important. If generated power is not used efficiently, it is unlikely that investment costs can be recouped within an acceptable time period. To increase the utilization of power in a village, that power should also be used in the village to help generate more income, and stimulate and contribute to economic development in the village. Equipment manufacturers, project planners, and developers can encourage productive end-uses by providing appropriate technical and institutional arrangements to enhance the overall economic viability of the schemes.

One success story of an MHPP project was the Tanjung Durian project located approximately 160 kilometers north of Padang. In this project, the Al-Hikmah Foundation provided funding for specific components, and the local villagers provided "in-kind" contributions of manpower and locally sourced building materials. The plant went into operation in June 2001. It is an 8 kW standalone MHPP plant that supplies power to 91 houses in the village. The village set up a cooperative in 2002 to be responsible for tariff collection and accounting. In exchange, the cooperative receives 20 percent of electricity sale revenues. To make it simple to manage, electricity tariffs are collected weekly in a lump sum amount based on the number of 10-watt bulbs. For each 10-watt bulb, customers pay Rp.1,500 per week. Additional Rp.2000 per week is charged for a television set. Lighting for street lamps, mosque and other public utilities is provided free of charge. In addition to evening lighting, during the daytime, the Al-Hikmah Foundation used the electricity to run a rice mill that was built alongside the powerhouse. The foundation buys grain for an average price of Rp.1,250 per kg and sells the milled grains for Rp.2,500 per kg. About 50 percent of gross income from the rice milling unit is used to pay operators and to cover other operational costs. The remaining 50 percent of gross income belongs to the foundation and is to be used for further expansion of the mini-hydropower facility, and for repair and maintenance.

A similar practice was repeated in other MHPP projects. Another example was the 15kW Cisompet mini-hydro plant in the Garut district, West Java, which went into operation in early 2002. The scheme was financed with a loan from Yayasan Bina Usaha Lingkungan (YBUL).[28] The plant supplies evening lighting to more than 80 households in the village. The consumers pay a per month fixed fee of Rp.15,000 for a 0.5 ampere connection. During the daytime, the turbine drives a multi-purpose mill via a direct drive transmission. A village cooperative was formed to manage and operate the scheme. About 50 percent of the income generated from the plant monthly is repaid against the loan to YBUL, and the remaining 50 percent covers daily operation and maintenance costs. The loan was provided for a period of 12 years. Revenue generated by the mill is split 50-50 between the cooperative and the mill operators. Accumulated funds at the cooperative are used for small loans to members. The Cisompet mini-hydro plant showed that a properly applied, standalone MHPP scheme can operate on a sustainable basis providing electricity supplies, as well as tangible benefits, for a rural community while repaying investment capital and thereby becoming financially sustainable.

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[28] YBUL is an NGO in Indonesia with focusing area of work in renewable energy and energy efficiency.

Until 1990, Indonesia was lacking local capacity and know-how on to produce quality mini-hydropower equipment, and on how to plan, design and construct proper mini-hydropower schemes. Such shortages had resulted in the failure of many mini-hydropower projects that were implemented at that time. As the MHPP began to focus on training locals and transferring know-how to suppliers, contractors, small private companies, and institutions in Indonesia, it helped increase the sustainability of existing projects, and prompted local contractors to implement more new mini-hydro projects. The success in mini-hydropower projects in Indonesia appears to have increased over the past ten years.

The know-how transfer increased local content in planning, designing, engineering, manufacturing, etc. of small- and medium-sized hydro projects (range up to 300 kW) to over 80 percent of total project costs. This resulted in a reduction of investment costs from about US$ 3,000-5,000 per kW to between US$ 1,500-3,000 per kW (including transmission and distribution), and in reducing reliance on foreign currency to finance mini-hydropower schemes in Indonesia. The expansion of mini-hydropower projects in Indonesia and thus the expansion of mini-hydropower manufacturers have created many jobs for the economy.

The MHPP has developed various mini-hydropower technology packages together with local manufacturers in Java and Sumatra that were used in over 100 installations during the past 10 years. Presently, mini-hydropower plants provide electricity to over 20,000 families and have resulted in a CO_2 emissions reduction of more than 4,000 tons per year. Most of MHPP are standalone operations. The first grid-connected MHPP was the Kalimaron mini-hydropower scheme in Seloliman, East Java. The plant was connected to the PLN grid in December 2003, allowing the excess power from the plant to be sold to PLN. The sales of excess power increased the project's revenue and allowed the owners to purchase power from PLN during periods when the hydro plant's output was insufficient. This arrangement is managed under a ministerial decree that requires PLN to purchase power from renewable energy producers smaller than 1 MW.

Bad planning, improper engineering designs, and/or use of low quality equipment can result in failed mini-hydro schemes, and can tarnish the reputation of mini-hydropower in general. By having MHPP as a center with expertise in the mini hydropower schemes available to work with local government in assessing potential sites, developing new projects, supervising the on-going construction, and monitoring existing projects helps to guarantee project success. MHPP staff could then carry out regular monitoring visits to the sites and conduct interviews with managers and operators to ascertain plant conditions and performance, and identify any problems.

4.3 Village Power Programs in Thailand

Thailand has a long history of using village power applications in many areas of the economy. The two main organizations implementing village power technologies are the Provincial Electricity Authority of Thailand (PEA) and the Department of Alternative Energy Development and Efficiency (DEDE). PEA is a public utility responsible for the distribution of electricity throughout Thailand with the exception of the Bangkok metropolitan area. PEA's service area covers about 99 percent of the total area of Thailand. DEDE is under the Ministry of Energy. Its responsibilities are to promote energy efficiency and energy conservation, and to develop alternative energy sources for Thailand. Solar energy and wind resources are being used for rural electrification in some parts of Thailand. The Thai government has also focused on producing biofuels, both ethanol and biodiesel, and is implementing a community level biodiesel production program. More details and lessons learned are discussed below.

Solar Home Systems in Thailand[29]

The Solar Home Systems (SHS) project was started in Thailand in March 2004. The project was implemented by PEA to fulfill the Thai government's policy to electrify every household in the nation by 2006.

As of 2003, statistics from the Ministry of Interior showed that there were 440,716 unelectrified houses in Thailand. These unelectrified houses were classified in three groups. The first group (approximately 150,000 houses) included houses located in areas, such as national parks, watershed areas, or military restricted areas, that are prohibited by law from any development. The second group consisted of about 50,000 houses that were located in areas not prohibited by law from development but that were very remote and difficult to access. Expanding the grid to these areas required a large investment and posed problems for PEA's electrification program. The third group included the rest of the houses that were under PEA's plan and budget to be electrified between 2004 and 2005. The SHS project targeted electrification of homes in Groups 1 and 2. A total of 203,000 houses were designated to be electrified under the SHS project. The project was set to be completed by the end of 2006.

The solar home systems installed in the project were small and provided only 120W AC power, enough to power two 10W fluorescent lamps and one 14-inch color TV for about four hours a day. However, they served the purpose of being the driving force behind the policy, which was to provide enough power to enable villagers to listen to government broadcasts via radios and televisions. A set of the solar home systems in the PEA's SHS project consisted of 120W solar panels, a 125 Amp-hour battery, an inverter, a charge controller, and mounting equipment.

The SHS units were installed at no charge to homeowners. The first system was installed in August 2004. PEA contracted with two private companies to work on the project—Solartron Inc. and a company operated jointly by three Thai solar companies—Bangkok Solar, Sri Uthong, and RCR. The contractors were responsible for installing the systems for homeowners. The contractors were also required to provide two types of training—one to homeowners and the other to the local government committee (Tumbon Administrative Organization—TAO or Or-Bor-Tor), which was selected by village residents to be in charge of village's general activities. For homeowners, the contractors made a poster explaining "Do and Don't" and put it near the system in every home,

[29] Information from the Provincial Electricity Authority of Thailand

where it could be seen clearly, and to provide homeowners with some basic training about system operation and routine maintenance. Training for TAO focused on how to conduct a system check-up, and make easy system repairs. The solar cells and most system components were imported, but local contractors fabricated the solar panels and assembled the systems. After the systems were installed, ownership was transferred to the homeowners. The village residents had full authority to manage and maintain the systems any way they desired.

The SHS project was completed with some delays from the original date of October 2006. The contractors reported a few problems that caused delays in system installations. One problem was due to an inaccuracy on the number of unelectrified houses where solar home systems were to be installed. By law all houses in Thailand must be processed for a house number, a house registration, and names of residents. However, in remote areas, residents did not always report the construction of new homes to the government and did not care to apply for house numbers or registrations. Also, residents did not always report to the government when they moved out of their homes. When the contractors were in the area ready to install the solar home systems, they found homes with no owners or homes without house numbers or registration, where they could not install the systems until after the homeowners had applied for, and received, house numbers from authorities. The project was also delayed due to a shortage of solar cells worldwide during the high oil prices of October 2004. Solar home systems were in significantly higher demand, especially in the European markets, during that time as homeowners worked to reduce electricity consumption. The contractors thus ran into problems posed by importing solar cells to make solar panels for the project. In addition, in December 2004, a few months after the project was started, the tsunami hit the southern part of Thailand. Many homes already surveyed and designated for the project were destroyed. A number of homes where systems were already installed were also severely damaged. PEA had to conduct a new survey to enlist homes for the project, and thus causing a delay in project completion.

The success of this project was questionable, and many lessons could be learned from it. One set of problems was due to the human factor. A year after the project was implemented, with 130,000 systems installed, about 4-5 percent of system components, mainly the inverters, were not operational. The problem was that homeowners attempted to use more electricity than the system's capacity of 120W. They plugged in appliances that consumed large amounts of electricity such as rice cookers, irons, and hair dryers even though they were told not to. Normally, the inverter would turn off the circuit when users attempted to draw power above system capacity. However, if the users still attempted to plug an appliance in several times, the inverter was ruined. In communities where there was no defined arrangement for who was in charge of system maintenance and no fees were regularly collected for a system repair, villagers did not know what to do when their solar home systems did not work. In many cases, solar panels were turned into places where villagers dried their clothes. Although the contractors provided warranties for the systems and components (e.g., two-year warranty for the system, 5 year warranty for solar panels, and 3 year warranty for inverters), the warranties were not valid if the system failed due to a natural disaster such as thunderstorm or flood, or due to improper use by homeowners such as forcing the system into an overload use—which seemed to be the cause of most system failures. More homeowner education was needed to ensure their understanding of what they should and should not do with their solar home systems.

The other problem contributing to difficulties with the project was that the government did not provide PEA with sufficient project funds. The cost per system was allocated at 25,000 baht (about US$625), which was only sufficient for a 120 W load per household. The system was too small and only allowed for the use of two lights and a TV. Homeowners were unhappy about the small load and thus intentionally overloaded the system, resulting in system breakdowns. In addition, because of the small budget, low quality inverters were used. With the total cost per house being fixed at 25,000 baht and the cost of 120 W solar panels at about 17,000 baht, only 8,000 baht remained to cover all other components, i.e., battery, inverter, etc. The contractors had to buy inexpensive, low quality inverters (which cost only about 2,800 baht). The systems thus failed easily.

There seemed to be problems from the start when the systems were given away to homeowners at no charge. The free systems made homeowners unappreciative and they did not feel a sense of ownership. It was worse when there was no monthly fee for use. In some villages, TAOs who were assigned to manage and maintain the systems set up a fund and collected monthly fees from system owners (varying between 50 to 100 baht per month). This fee would be used for system maintenance and to purchase new parts as needed. Some TAOs, however, did not collect any fees from system owners as they tried to make the owners happy in order to gain their votes in future elections. Some villages lacked any maintenance arrangements, and each homeowner was responsible for their own system repairs. With no fee collections and no pre-arrangement for system repairs, when systems failed due to improper use and contractors did not have to provide warranty service, systems were not fixed and therefore not in use.

Having the TAO staff maintain the systems also posed another problem. The TAO staff was elected, and thus the staff that was trained to maintain the systems might not be re-elected for a new term, and newly elected staff were not being trained in system management. Experience from rural electrification in other economies showed that hiring professional technicians to do regular repair and maintenance increases the project's sustainability.

Training and education of users, professional technicians for routine checks and system maintenance, sufficient budget for the project, as well as implementing a user pay principal would have increased the chance of this project's success.

Renewable Energy Hybrid Systems in Thailand[30]

In the past, using diesel power generation was the PEA's common practice for supplying electricity to remote villages because of its low upfront costs and the short time required to construct a small diesel power plant. However, bringing diesel to a remote site

[30] Document from the Provincial Electricity Authority of Thailand (in Thai)

incurred high transportation costs, as most remote sites were not easily accessed. PEA implemented the Renewable Energy Hybrid Systems project as a pilot project to find a way to decrease expenses of providing electricity services to residents in isolated islands and remote areas who currently receive electricity from diesel generators.

Four locations were selected for this pilot project—three locations in the north and one in the eastern part of Thailand. Three types of hybrid systems were selected. The test was basically to incorporate PV panels into existing systems of diesel generation—both off-grid and grid-connected systems. One system was a photovoltaic/micro-hydro/diesel/ battery system installed at Khun Pae village in Chom Thong district, Chieng Mai province. This site previously used electricity generated from micro-hydropower and a diesel generator. PEA added into the existing system, 7.2 kW of solar panels, a 110 kWh battery, a 40 kW inverter, and an automatic control system.

The second system was a photovoltaic/diesel/battery system installed at Ko Kut District in Trad province, in eastern Thailand. The system consisted of 12 kW of solar panels, a 110 kWh battery, a 40 kW inverter, and an automatic control system, added into the existing diesel power station. The goal was to reduce the use of diesel fuel as Ko Kut is a remote island and the cost of transporting fuel to the site was very high.

PEA also installed a PV grid-connected system in two locations—one at Den Mai Sung Village, Ban Tak district in Tak province, and the other at Mae Ka Si Village, Lat Yao district in Nakhon Sawan province. In both locations, a new grid-connected 50 kW inverter, and an automatic control system were installed to supply electricity in parallel with PEA grid systems.

So far PEA has had only a few problems with their systems. One problem that PEA encountered, and would avoid in the future, was caused by using imported system components from a foreign company with no local representative who could tend to system maintenance and repair when required. When the hybrid system at Ko Kut was struck by a lightening and the system inverter (which was imported from abroad) was damaged, PEA could not find a Thai company to fix it. PEA then had to replace it with a new inverter from Leonic (the only Thai company that produces large sized inverters). Besides that the other minor incident occurred when a lizard got inside the control box of the hybrid system at Khun Pae village and caused an electric short to the solar panels.

Community-Level Biodiesel Production in Thailand[31]

About 90 percent of the oil used in Thailand is imported. The main use of oil in Thailand is in the transport sector where diesel accounts for about 44 percent of total oil consumption. The Thai government has implemented a policy to promote production and use of biodiesel as an alternative fuel to replace expensive diesel. The Thai cabinet resolution dated January 18, 2005, set a target to initiate commercial biodiesel distribution in Thailand in 2006, and to produce 8.5 million liters per day of biodiesel, or to introduce a 10 percent blend of biodiesel into all diesel fuel, by 2012. Several

[31] Document from the Department of Alternative Energy Development and Efficiency (in Thai)

biodiesel projects were launched in Thailand to respond to the government's policies both at a small scale for community development and at an industrial scale, using raw materials available in Thailand, especially palm oil, used vegetable oil, and jatropha oil—an oil crop called Sabudam in Thai.

The Royal Thai Navy was among the pioneers in research on biodiesel production and demonstration. The Royal Thai Navy's biodiesel project started in 2001 by the Department of Naval Dockyards with the purpose of finding an alternative to diesel oil, which was consumed at about 37 million liters annually to run the thousand or more diesel engines used by the Royal Thai Navy. In 2004, the Royal Thai Navy was involved in designing and building a prototype biodiesel pilot plant, of 2,000 liters per day capacity, for the Royal Chitralada Project. In this project, used cooking oil from the canteen of the Royal Chitralada Palace was used as a raw material for biodiesel.

The Department of Alternative Energy Development and Efficiency (DEDE), an agency under the Ministry of Energy, which has a direct responsibility for seeking alternative fuels for Thailand, has been working in cooperation with several organizations in the research, development and demonstration of biodiesel. DEDE launched the project "Community Biodiesel Research, Development, and Demonstration" in June 2004 at San Sai District in Chieng Mai, to provide prototypes for biodiesel production at the community level. The project succeeded with a joint effort of various public and private organizations, including the Department of Energy Business, the Pollution Control Department, the Department of Naval Dockyards, Prince of Songkla University, PTT Public Company, and Bangchak Petroleum Public Company. Financial support for the project came from Thailand's Energy Conservation Fund. Work in the project included the establishment of the community-level biodiesel production system, demonstrations of the use of biodiesel in vehicles, studies on economic and environmental impacts, and public relations campaigns to educate local people. Trial production began in April 2005 using oil crops, used cooking oil, and animal fat as raw materials. The project aimed to produce 2,000 liters of biodiesel per day through the transesterification process. The project started with 2 percent biodiesel blended with 98 percent regular diesel, and four months later the blend was raised to 5 percent biodiesel with 95 percent regular diesel.

In the initial stage, a target was set to encourage 1,000 taxi pickup trucks, out of 3,000 in the city of Chieng Mai to switch from diesel to biodiesel. Two gas stations, one run by PTT and the other by Bangchak Petroleum, joined the project for biodiesel distribution. As the project was new, DEDE faced the problem of public participation. Only 100 drivers registered as customers in June 2004 when the project was launched. Out of this number, only 15 used the services at the two gas stations. The reason was that they did not believe in the new product. Before this DEDE's biodiesel project was launched in Chieng Mai, some private firms produced and sold what they called biodiesel produced from vegetable oil blended with diesel and glycerin. The price was two to three baht lower than that of diesel at that time. The local drivers were very happy with the prices. However, when they drove their trucks to places where temperature was cool such as on high mountains, they found that they could not start their truck engines in the morning because the oil became too thick. So when DEDE started to advertise their newly produced biodiesel, local drivers did not believe it was a good product and did not want to use it.

Realizing the public perception problems, DEDE focused more on public campaigns to drivers on the benefit of biodiesel. DEDE sent a team from Bangkok to campaign in Chieng Mai. Every day DEDE staff visited pickup truck drivers, distributed posters, educated drivers, and let them know that the new biodiesel was up to standard. DEDE began to gain more and more customers. The number of biodiesel gas stations was increased from two to five, and there are now seven. The project now produces more than 2,000 liters of biodiesel per day. In the future, if feedstocks are sufficient, DEDE may produce additional biodiesel to replace fuel for low-speed diesel motors used by trains.

DEDE started two community-level biodiesel pilot projects in 2005—one was at Payakkarum Temple, Sriprachan district in Supanburi province, and another at Na-Wa Agriculture Co-operative in Nakorn Panom province. DEDE has offered training to those who are interested in this technology and wish to produce biodiesel for use in their own communities. Any community with potential for biodiesel production may write to DEDE asking for the establishment of the production system. The community must consist of at least 20 households, with demand for diesel consumption of at least 175 liters per day. There must be at least seven persons who will take charge of managing the project. The Ministry of Energy will provide equipment and training. The participating communities will be responsible for finding raw materials and plant locations, and for operating and managing the plant and project.

At present, community-level biodiesel systems are being established in communities all over Thailand to help generate income for local people, develop alternative energy on a sustainable basis, and to reduce the economy's foreign currency expenditure on oil imports. DEDE has goals to establish community-level biodiesel production systems in 70 communities. The system size is 200 liters per day. To date, 46 communities have been approved to join the project. A total of 17 biodiesel plants have already been set up in those approved communities with training also being provided. Most communities will use cooking oil and jatropha oil as raw materials. Some communities will use palm oil and coconut oil.

His Majesty the King of Thailand was a pioneer in alternative fuels in Thailand. His work on renewable energy started in 1979. His projects included biogas, ethanol, gasohol, diesohol and pure palm oil. He received a Brussels Eureka 2001 award for the 50th World Exhibition of Innovation, Research and New Technology in Belgium for his innovation in the use of palm oil to make biodiesel. To disseminate the King's initiatives on bioenergy projects as well as to celebrate his 60th year anniversary to the throne, several Thai organizations, including the National Metal and Materials Technology Center, the Royal Thai Naval Dockyard Department, Thailand Institute of Scientific and Technological Research, DEDE, Kasetsart University, the Royal Chitralada Projects, and the Chai Patana Foundation have developed the Integrated Community Biodiesel Project. The pilot project is located at the Crown Property Bureau's Plot in Saraburi province.

The project is designed to demonstrate a community-level (200 liters per batch), life-cycle biodiesel production from growing feed plants (i.e., palm oils and jatropha oil) to produce biodiesel and its byproducts that can be used to make soap, solid fuel and fertilizer. Biodiesel can be used to run diesel generators, farm tractors, and other agricultural machines. The solid fuels can be used as household fuels or in a community power plant. There are over 7,000 communities (Tumbon) in Thailand, each of which uses about 200 liters of diesel per day. If each community could produce its own diesel for use within the community, that would save the community money and would generate supplemental income from sale of byproducts.

An obstacle to biodiesel use in Thailand was that when the fuel was first introduced, people did not want to use it for fear of ruining their vehicles. One of the factors contributing to the present project success was the public education campaigns that gave local people a better understanding of biodiesel and prompted acceptance of the project.

Village-Level Mini Hydro Project in Thailand[32]

A mini-hydro project was implemented by DEDE to provide electricity to people in remote villages where connecting with the utility's grid was cost prohibitive, and where hydro resources are available. In the past, it was expensive to implement a hydropower project in Thailand because, although a generator could be produced locally, the hydro turbine had to be imported. There was also a problem regarding lack of local technicians to maintain the system. After 1978, DEDE was able to develop its own hydro turbines (both Cross Flow and Pelton), develop electronic load controllers and hydraulic governors, and to improve the quality of generators used in hydro systems. That has made it possible to have all components for a hydropower system produced locally and thus lowered costs of a hydropower system by over half. DEDE also reduced the size of its typical large hydropower projects to a smaller, village sized mini-hydro projects.

A system is generally composed of one or two Pelton or Cross Flow turbines with 20 to 60 kW capacity per turbine. The water head ranges between 20 to 100 meters and water flow rates are between 60 to 100 liters per second. The generator is designed to be between 25 to 75 kV-Amp/ 380 volt with an electronic load controller or a hydraulic governor. The generator system is housed in a small wooden, 10 to 30 square meter building. Power lines are connected to each resident's house. Power is normally transmitted at 3500 V with a transformer to 380/220V low-voltage distribution lines.

The project is a cooperative effort between DEDE and local citizens. To set up such a mini-hydro operation, a group of local residents must agree to adopt the project in their village and commit to work together on its implementation. DEDE staff will then visit the site to determine the hydro resource potential. If the site shows good potential for a hydro project, DEDE will establish a budget and work with the villagers to build a hydropower plant in that village. The project is run on a cooperative basis. Village residents will jointly own the power plant by owning shares in the cooperative but do not

[32] Document from the Department of Alternative Energy Development and Efficiency (in Thai)

have to pay cash for cooperative shares. Instead, they can provide their own labor or donate materials for the hydropower plant construction. DEDE will appraise labor and donated materials for their value, and distribute cooperative shares at the equivalent value to residents who've provided them. DEDE provides hydro turbines, equipment, and all materials needed for the project that cannot be obtained from villagers. DEDE will send technicians to work on the project with villagers, install transmission lines from the power plant to the village, and train villagers to maintain the system and replace spare parts when needed. Any major repair of the system will be undertaken by DEDE's technicians. Villagers are also trained to manage the cooperative. The cooperative collects user fees monthly at the same rate as the electricity that would come from the utility's grids. The fees are used to pay for a local technician to maintain the system. Net profits from power sales, after all expenses, are partly designated to fund activities in the village.

Currently, DEDE has completed around 80 village-level mini-hydro projects in Thailand, mainly in the northern part where hydro resources are available. However, at present, only a total of 39 village-level mini-hydro projects, with total capacity of 1,110 kW, are still in operation. The principal reason that some of the DEDE's hydropower plants discontinued their operation was that the existing hydro systems were too small and could not provide enough electricity to meet the villages' growing demands. DEDE designed the hydro projects based on numbers of households in the village and their basic need for electricity at the time when the project was commenced. As time passed, the villages grew larger, with more residents, more income, and a change in lifestyles, and the residents desired electricity beyond what was initially planned for to satisfy basic daily needs. Because it could not provide the desired power, villagers became unhappy with the existing hydropower plant provided by DEDE.

At the same time, PEA worked to electrify all villages not located in an area where land development is prohibited by law. PEA would map the areas for grid extensions each year but due to the lack of coordination between agencies, PEA's grid extension lines were sometimes placed in areas where DEDE's existing hydropower plants were located. When the villagers had the option of using electricity from grid, they would stop using electricity from their local hydropower plant as they were paying the same rates from both power sources while the grids provided unlimited amounts of power. The existing mini-hydropower plant thus became abandoned.

The other reason reported for the abandonment of some village-level mini-hydropower plants was the high turnover of local technicians who maintained the plants. Some cooperative hydropower plants were not managed well and could not collect revenues to pay enough to keep the local technicians employed. The villages thus experienced too frequent changes of maintenance personnel, which interrupted the job and made it more and more difficult to hire new staff. Thus the plants were neglected.

DEDE now knows about these problems and has been working to restore these neglected hydropower plants. DEDE's new strategy is to fix the neglected hydropower plants so that the systems work properly, and then to transfer the system to the local village government representatives (TAO) and the village cooperatives. The hydropower plants will be modified so the systems work parallel to PEA's grids. The power generated from the hydro plants will be sold to the PEA grid, instead of to individuals, and villagers will buy all power from PEA that can be accessed in unlimited amounts. This concept has been working so far. DEDE completed a restoration of three neglected hydropower plants, is working on two projects at present, and has set a budget to fix another 25 old hydro plants.

4.4 Village Power Programs in Malaysia

The most important renewable energy resources in Malaysia are biomass and solar. Malaysia has intensified the development of renewable energy and in 2001, announced that renewable energy was the fifth fuel resource under the economy's Fuel Diversification Policy as stipulated in the objectives of the Third Outline Perspective Plan for 2001-2010 and the Eighth Malaysia Plan. This section shows examples of renewable energy programs implemented in Malaysia including the Small Renewable Energy Power Programme and the Centralized Solar Power Station.

Small Renewable Energy Power Programme in Malaysia[33]

Through the "Fifth Fuel Strategy," the government advanced the development of renewable energy and targeted a 5 percent contribution of renewable energy to the economy's electricity mix by 2005. To support the government's strategy to intensify the development of renewable energy as the fifth fuel resource, the Special Committee on Renewable Energy (SCORE) initiated the Small Renewable Energy Power Programme (SREP) in May 2001. SREP aims to promote the growth of small power generation plants that utilize renewable energy, facilitate the expeditious implementation of grid-connected small power plants based on renewable energy resources in order to enable them to sell their electricity to the utility through the distribution grid system, and thereby promote and encourage the development of more efficient renewable energy technologies. Small power-generation plants that use renewable energy can apply to sell electricity to the utility through the distribution grid system. The producers will be responsible for all costs of the grid-connection, the relevant utility system reinforcement (i.e., electric cables, transformer, switchgears, and other protection equipment), and the necessary metering installation. The renewable energy electricity producer will be given a license for a period of 21 years, effective from the date of commissioning of the plant. SREP applies to all types of renewable energy, including biomass, biogas, municipal waste, solar, mini-hydro, and wind. The capacity of renewable energy power plant designed for sale of power to the grid can be greater than 10 MW, but the maximum capacity plant that will be allowed to sell power to the distribution grid is 10 MW.

Additional incentives were also provided to companies that use renewable energy and which submitted their project applications between September 21, 2002 and December 31, 2005. Those companies would be eligible for Pioneer Status or ITA, and if the

[33] www.st.gov.my/index.php?option=com_content&task=view&id=563&Itemid=1156

companies are located in the promoted areas, they would also be eligible for higher exemptions/allowances under Pioneer status. To receive these incentives, the companies must implement their projects within one year from the date of approval. The biomass sources specified under this incentives included palm oil mill/estate waste, rice mill waste, sugar cane mill waste, timber/sawmill waste, paper recycling mill waste, municipal waste, and biogas (from landfill, palm oil mill effluent, animal waste, and others). The incentives were also extended to the use of hydropower (not to exceed 10 MW) and solar power. The energy forms referred to electricity, steam, chilled water, and heat.

As of July 2004, sixty renewable energy projects were approved by the Ministry of Energy, Water and Communications. Of the total, only seven projects had signed renewable energy power purchase agreements and the total capacities from these seven projects were only 33 MW, far below the target of 5 percent (or the equivalent of 500 MW) set in the 8th Malaysia Plan.[34]

Centralized Solar Power Station in Malaysia[35]

Malaysia built its first centralized solar power station in 2003, in the remote village of Kampung Denai. Kampung Denai is located about 35 kilometers away from the nearest main road that connects Rompin and Mersing, in the state of Pahand. The residents of Kampung Denai are aborigines known as Orang Asli. There were about 158 people in 22 households in Kampung Denai. The village was far from electricity grids. Residents used candles and kerosene lamps for lighting at night. The residents acquired an 18.6 kW diesel generator to provide electricity supply in 2001. The generator ran from 7:00 p.m. to 11:00 p.m.

The project was undertaken by Tenaga Nasional Berhad (TNB), the principal electricity utility in Malaysia. The objective of the project was to design and install solar power stations at remote locations and to develop a standard design of standalone solar power stations suitable for Malaysia. Kampung Denai was chosen to receive the first centralized solar power station because the village has a primary school for the Orang Asli children. The solar station would provide electricity for longer hours and with greater reliability, and would help students learn in a more comfortable environment. In addition, houses in these communities are arranged in a way that makes electrical wiring easier. The village was also far from the last transmission line making it costly to extend the electricity grid. The village's remote location and local rough road made it cumbersome to bring in diesel for the generator.

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[34] "Malaysia: Biomass and Solar," Globe-Net's Market Report 1/3/2007, see www.globe-net.ca/market_reports/print.cfm?ID_Report=761

[35] Iszuan Shah, Syed Ismail, Azmi Omar, and Hamdan Hassan, "Pilot Centralized Solar Power Station in Remote Village, Rompin, Pahang," Proceedings of the National Power and Energy Conference (PECon), Bangi, Malaysia, 2003.

The solar sizing was done to accommodate a combined load for both home and school applications. The maximum home demand was measured at 4.2 kW, but the system used a 10.5 kWp solar system (60 solar panels with each panel rated at 175W) to cover the school load as well. The system also included a 10 kW inverter, 150 kWh batteries, and other balance of system. The solar energy stored in these batteries lasts for at least five days. However, a diesel generator set with a capacity of 12.5 kVA was also installed as a backup power source, and to be used during monsoon season. The equipment was imported from an Australian based company—Advanced Energy System. Since Malaysia does not experience a seasonal climate, the electricity generated by the sun remains relatively constant throughout the year. The system provided electricity to 15 of the total 22 households in the first stage of the project with others brought online when the houses were upgraded to meet safety standards. Electricity production normally started at 9 a.m., peaked at noon and stopped at around 6:30 p.m.

The system used a bidirectional controller that could operate between solar, battery, and a generator set. In addition, the system enabled the controller to be integrated with other renewables such as wind or a micro-hydro turbine. To save space for future extensions, the solar panels were mounted on top of the container that also acted as a shield for the generator set from heat and rain. The system voltage was 120V to stabilize system reliability and improve voltage drop. The controller was also used to download data on solar radiation, temperature, and system output such as solar panel, battery, generator, and load to users.

There has been no charge for electricity from the station at Kampung Denai since the project began. The government, however, plans to charge the residents in the future after they have a greater ability to pay. The villagers used to earn their living by fishing in the river inside the jungle. They lived at a subsistence level and did not have sufficient earned incomes for such cash payments. The local government allowed every family 6-8 acres of land to plant oil palms, a major cash crop and export of Malaysia. The government hopes that after two to three years when the villagers can get a harvest from their land, they will be able to pay for their electricity. TNB plans to charge the villagers the same amount it charges customers on the national grid, where electricity comes from fossil fuel powered generators (about 24 Malaysian cents per kilowatt hour).

So far the station has reportedly provided continuous reliable and maintenance free electricity. There are needs and opportunities to build more centralized solar power station like the Kampung Denai station. However, it is difficult to get such projects off the ground. Several factors were identified as obstacles. Those included the capital-intensive nature of the project, restricted access to finance, and lack of awareness about technology (including limited technical support and incompetent maintenance service).

4.5 Village Power Programs in the Pacific Islands

Experiences from the PV-based rural electrification program in Kiribati and the Marshall Island are good lessons for APEC economies implementing renewable energy projects.

They showed that institutional factors could play a major role in the failure or success of implementing a local renewable energy project.

PV Based Rural Electrification in Kiribati [36]

The Republic of Kiribati (former a British Colony, the Gilbert Islands) consists of 33 atoll type islands with a total population of about 80,000 people. The majority of residents (over 30,000) live in the southern part of Tarawa, which is the capital island. The rest live in the 21 atoll islands. The capital island, South Tarawa, is grid-electrified with power from diesel generation. Besides the capital island, there is a short grid extension into North Tarawa, a small local grid developed on Christmas Island, and small diesel or petro-generators to power outer island government offices, and larger secondary schools.

In 1984 the Foundation for the Peoples of the South Pacific (FSP), a U.S.-based non-governmental organization, established the Solar Energy Company of Kiribati (SEC) with funding from the United States Agency for International Development (USAID). SEC was set up as a private corporation with the purpose of promoting and selling PV systems to the Kiribati rural households. The company sold, installed, maintained, and provided services on demand to customers. The shareholders of SEC included the Bank of Kiribati, and the Ministry of Public Works and Utilities (MPWU).

The SEC had tried to address issues and problems that other Pacific Islands faced in implementing their PV rural electrification projects, and tried hard not to repeat the same problems. One problem that the SEC learned of was that system components such as lights, controllers, and batteries had to be selected carefully so as to withstand harsh environmental island conditions with salty air, high humidity, and high temperatures. The SEC also learned that a lack of trained personnel available to provide maintenance and repair services was common in other projects, and thus they developed a competent technical staff and provided them with periodic training. Other projects showed that inadequate stock of replacement parts kept the systems from being properly maintained, so the SEC stockpiled a full set of replacement components to sell to customers as needed. The SEC prepared intensive installation and maintenance manuals in the local language. The SEC also provided professional installation services to customers (with some charges) to avoid problems with poor quality installation that was commonly found in other projects. In addition, the SEC allowed customers with known credit or who could provide guarantees of payment to buy systems under credit terms so low income people would have an opportunity to obtain the systems. Despite the rational approach to their operation and the grants from USAID to support the operation, the SEC still failed and went bankrupt in 1989.

[36] Akura, Terubentau, Herbert Wade, and Marc Torra, "Review of RESCO-based Kiribati Stand-alone PV Program," Proceedings of the APEC 21st Century Renewable Energy Development Initiative (Collaborative I): Technical Workshop to Support Village Power Applications, Canterbury, New Zealand, 7-9 November, 2004, APEC Energy Working Group (www.apecenergy.org.au).

In an attempt to proceed with further PV utilization in rural Kiribati, the MPWU conducted a nationwide survey of rural PV system purchasers to investigate the problems. The survey results showed that of the total 270 PV systems sold in Kiribati, approximately 90 percent were only marginally operational or not in use at all, and the principal problems were related to improper maintenance and installation. Almost all systems had not received any maintenance other than replacement of failed components. Components were also found dirty and damaged by insects. About 50 percent of the systems had been installed without a charge or discharge controller, which caused damage to the battery and made battery life shorter than it should be. Other installation problems included serious wiring deficiencies (usually in the form of twisted connections or wires that were too long for their size), and improper placement of PV panels (either not oriented well toward the sun or located in areas that are too shady). The survey also showed that in about 43 percent of the systems, the original deep discharge batteries were replaced with automobile batteries that had inadequate capacity and a short life expectancy. Many system owners also replaced the original high-efficiency fluorescent lights with automobile headlights or tail lights when fluorescent bulbs failed, while others added more appliances to the systems, which resulted in demand load higher than the capacity of the systems as designed.

The high rates of system failure caused dissatisfaction in customers, and general distrust of PV systems as an electrical supply source. The sales of PV systems in Kiribati dropped significantly causing the bankruptcy of the SEC.

To solve the problems, the government, with recommendations from an outside consultant, decided to convert the SEC from a sales-oriented organization to an energy service company. Several changes were made in the SEC operations, which finally turned the SEC from a failed organization to a world model of a successful PV based rural electrification. Those changes included a new practice of having systems on individual households be owned and maintained by the utility (although appliances and house wiring after the battery connection would be owned and maintained by the homeowner). Household users were required to sign a contract in which they agreed to pay an installation fee; not tamper with any of the utility-owned equipment; maintain panel areas to be free of shade; pay regular fees; and use the system according to the published guidelines, which included not adding any appliances to the system without prior permission from the utility. In return, the utility would provide repair services as needed and replace any failed parts at no cost. Monthly fees were set based on actual cost of operation and maintenance. Fees would be different for different types and sizes of installations (higher fees for higher capacity to operate more power-consuming appliances). The SEC also set up rural electrification districts. Each district would be of a size (set for a maximum of 125 systems) that would allow one SEC employee, designated as a field technician, to provide proper services to all users. If more than 125 systems were installed, more districts would be set up. The field technician was a full-time utility employee who would visit each installation once a month to check the equipment and collect monthly fees from users. The field technician could call a senior technician at the main office for assistance with troubleshooting or repair problems that were beyond his knowledge or experience. A senior technician from the main SEC office would also visit each district twice a year to audit the field technician's performance. Each district also had a users' committee consisting of five to seven persons elected by all users in the district. The committee was responsible for conveying complaints and requests from users to utility management and for communicating with other users on related utility matters.

Three pilot projects were conducted from 1990 to 2005 following these new rules—one with support from the Japan International Cooperation Agency (JICA), and the others with a support from the European Union. These pilot projects were highly successful, proving that the new concepts of the SEC have been working well, and thus larger scale implementation has been made to more remote islands. After the pilot projects, the solar capacity in Kiribati has been increased seventh-fold from 310 systems to 2,100 systems, and the number of electrified islands has increased from 3 to 18. Existing users were satisfied with their PV systems and a large majority considered their PV systems to be superior to a grid connection. The users reported that their quality of life was improved as they can complete their work and socialize at night, and can have radio and cassette players for entertainment at any time. There was also a report of improvements in health services due to the availability of emergency radio communications, good lighting, and vaccine refrigeration at island health centers. PV electrification has also lowered impacts on the environment as less diesel is being burned for power.

Solar Electrification Program in the Marshall Islands [37]

The Republic of the Marshall Islands (RMI) consists of 26 dispersed atolls in the central Pacific. The RMI population is about 52,000 people. About two-thirds of the residents live on two islands; the rest live on outer islands in small communities. Most households on outer islands use kerosene for cooking and lighting, which poses health impacts, safety issues, as well as environmental issues for the residents.

In 2003 the RMI adopted a "National Energy Policy Vision" that emphasized renewable energy, especially PV, as the long-term alternative source to replace imported petroleum products for electricity production in the Marshall Islands. The government established the Outer Islands Solar Electrification Program with a goal to provide basic lighting and power to every household in the outer islands by the year 2010. The program charged a US$100 installation cost per unit and a US$12 monthly fee per household for the use of a solar system, which was less expensive than the monthly minimum of US$13.30 per month that users had to spend for kerosene and batteries. The $12 monthly fee was used to stockpile spare parts for system replacements and to pay for Island technicians' salaries. The RMI has learned that failure to address maintenance issues and to provide maintenance funding has resulted in a failure in many past solar projects in the Marshall Islands and other Pacific Nations. A typical basic solar system of two pole-mounted 75 W panels would supply up to four fluorescent lights, a small LED night-light, and a multi-voltage power outlet for connection to small radios.

[37] Tom Roper, "Small Island States—Setting an Example on Green Energy Use," RECIEL 14(2) 2005: ISSN 0962 8797.

Many lessons can be learned from the RMI's solar electrification program. One main conclusion drawn from the program was that the existing utility must operate, maintain, and collect fees. Village owned, government owned, and individual owned solar units generally do not work because of inadequate maintenance. Field technicians should have ready access to technical assistance and receive regular training. Trained maintenance personnel should make frequent visits to users to ensure proper operation of the systems. Spare parts must be readily available for maintenance to avoid weeks or months delays between need for a spare part and receiving it from overseas. In addition, it has been learned that when fees are collected by a local community organization, collection discipline lacks, and funds are often used for other community projects instead of being set aside for solar equipment repairs. The RMI solution in this matter is to have the utility, the Marshalls Energy Company—MEC, send a "non-island" local to collect payments, and have all payments sent to the MEC's head office where payment records will be maintained on an atoll-by-atoll basis.

The involvement of, and commitment from, the community is also important to make a solar project sustainable. The utility thus should also place an emphasis on consultation with each community on all aspects of planning, installation, service, and payments.

Chapter 5

Recommendations on Village Power Technologies

Power outages often happen during disasters. Village power technologies can increase resilience and help communities respond to and recover from disasters more quickly. Village power technologies can be used during emergencies to provide lighting for shelters and rescue teams, to heat shelters, heat water for medical operations, purify drinking water, refrigerate medicines, charge electric appliances, pump water, power traffic control devices, advisory radio systems, and communication equipment. Solar systems are mobile, durable, quiet, non-polluting, modular, easy to install, very low maintenance, and very reliable. They are invaluable in many situations and are especially useful in the aftermath of a disaster. Village power technologies using wind and hydropower are less flexible than solar energy for use in disaster relief as they are less mobile and more site specific than, for example, a portable solar generator. However, if the resources are available, they can also provide useful services in various applications, especially in community reconstruction.

This chapter provides a list of village power technologies that have been used and proven useful for disaster response. The chapter also discusses the village power technologies that governments should consider adopting when reconstructing communities. These technologies will be invaluable to communities in the long run and will help communities better withstand future disasters. In general, technologies for disaster response are portable renewable energy systems such as portable solar generators, while those for community reconstruction are fixed renewable energy systems. However, some village power technologies suitable for disaster response are also appropriate for more permanent use when communities are reconstructed.

Only selected village power technologies for disaster response and community reconstruction are provided in this chapter as examples.[38] A complete list of renewable energy products that can be used for disaster response and/or reconstruction can be found in another APEC project entitled APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): Renewable Energy Products Database: Paving the Way for Deployment of Renewable Energy.[39]

5.1 Village Power Technologies for Disaster Response

This section discusses village power technologies that could provide useful services to an economy in disaster response. As electricity is one of the most critical services needed in the aftermath of disasters, most technologies suggested for disaster response are those

[38] Disclaimer: TDP does not endorse any products or companies mentioned in this report, does not guarantee qualities and performances of the products to be as described, and is not responsible for accuracy of the product information.

[39] See www.egnret.ewg.apec.org; or www.technologydevelopmentpartners.org/apecdb/default.htm

that provide electricity for various applications. Solar energy systems are more mobile and modular than other village power technologies. This allows solar-based systems to be moved easily when and where they are needed, and makes them easy to expand to fit changing needs. Most of the village power technologies recommended for disaster response are therefore solar energy based systems. Solar systems have already provided emergency power in the aftermath of many past disasters. A few examples of solar power used in disaster related activities are given below:[40]

> The 12 Volt Catalog (a PV Distributor) provided 30 small portable PV systems for use at various disaster shelters, medical facilities and emergency management offices after Hurricane Hugo in 1989. The systems used either Sovonics Solar System or ARCO Solar PV modules connected to a deep cycle Interstate Battery. The systems were used to power 12 VDC fluorescent lights, fans, and ham radios.
>
> A trailer mounted, PV-powered generator was used to power law enforcement traffic facilities and an orphanage after Hurricane Hugo struck South Carolina in 1989. The unit was built by the Arizona Solar Energy Office and Photocomm and supplied 12 VDC, 115 and 220 VAC of electrical power from a 2640-watt peak (Wp) PV array.
>
> A trailer mounted, PV-powered generator built by Barrett Manufacture was used for earthquake recovery efforts at Northridge in Los Angeles, California, U.S. in 1991. The unit contained 4 Siemens 48-watt PV modules, and provided standalone electrical power at both 12 VDC and 120 VAC.
>
> PV-powered water purification units were provided by Miox Corporation to produce clean water for people after Hurricane Luis struck the Virgin Islands in September 1995.
>
> The Florida Solar Energy Center and Sandia National Laboratories provided PV power systems to the Field Epidemiology Survey Team (FEST) from the University of Miami for use in four medical clinics after Hurricane Andrew struck the U.S. state of Florida in 1998. The clinics provided urgently needed medical services for people who had been injured during the storm as well as during the cleanup and reconstruction. Each system consisted of a 1-kilowatt peak (kWp) PV array, battery bank, controller, and a 2 kilowatt-hour (kWh) DC/AC inverter.[41]
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> Better Energy Systems,[42] a company based in the U.K., donated a case of Solio™ solar powered chargers to the Baton Rouge Fire Department to use after Hurricane Katrina hit New Orleans, Louisiana in 2005. The Fire Department sent Solio

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[40] William Young, "Disasters and Energy Security Management," Presented at Caribbean Solar Energy Society, Sustainable Applications for Tropical Island States, Port of Spain, Trinidad, WI, November 11, 2003, Florida Solar Energy Center (Publication Number: FSEC-PF-372-03).

[41] http://jxj.base10.ws/magsandj/rew/2002_05/light_darkness.html

[42] www.solio.com

chargers to nurses and doctors at EMS shelters and to the search and rescue teams in Franklin County and other areas hard hit by the hurricane. When Hurricane Katrina devastated New Orleans it knocked down all power and phone lines. The Solio chargers were used to charge cell phones, enabling doctors and rescue teams to call for help and supplies to facilitate relief efforts and to contact families in other states. Upon seeing the Solio chargers' benefits during the Hurricane Katrina relief effort, American Red Cross now includes a Solio charger in all communication kits for Emergency Response Teams to ensure that an alternative power source is always available for vital communications. A Solio charger is about the size of a cell phone and weighs only about 5.8 ounces.[43]

Solar power is most appropriate when low power is needed and when power will be needed for a long period of time. When power distribution lines are destroyed, when power outages are long, and extensive areas are damaged, PV can provide power to meet the emergency demand. The systems can be sized for specific power needs, from the low power needed to charge batteries to larger power sources used as standalone power systems. However, for applications that require hundreds of kilowatts of emergency power, PV power is not currently cost-effective when compared to gasoline or diesel generators.

Solar power systems can range from a small capacity of 2 watts used to charge a battery to over 1 kilowatt (kW) to provide lighting and other needs for rescue teams or at shelters. It is recommended that solar systems used in disaster relief be designed ready for immediate use, and be designated for specific emergency applications, such as one dedicated to battery charging, one to power a radio, and one for a weather station. This section thus lists solar power systems separately based on applications. For example, large solar powered generators are listed separately from small solar power systems for battery chargers or solar-powered radio systems.

The following are some applications that can be powered by solar energy.

Solar-Powered Generators

Portable fossil-fueled engine generators are commonly used following disasters to provide electricity to shelters, rescue teams, health clinics, businesses, and residences. Most engine generators are powered by diesel, gasoline or propane. Although these engine-powered generators can provide power reliably, they are noisy, annoying, and can be dangerous if users are not trained to operate them. They can also have very short life spans. Obtaining fuel to run these generators can also be a problem during disasters when roads are damaged, preventing vehicles from transporting fuel or if no power is available to pump gas from fuel stations.

Portable solar power systems are ideal for providing electricity when on-grid power sources are not available. They are very useful for disaster relief when power outages

[43] www.solio.com/v2/press-room/press%20releases/pdfs/PR6%20-%20Katrina%20V4.pdf

commonly occur. Portable solar power systems can be used to replace portable diesel and gasoline generators and thus reduce reliance on fuel sources that may be expensive and scarce following a major disaster. They can provide electricity to be used immediately, or stored in batteries for later use.

A solar-powered generator normally includes solar panels, batteries, a charge controller, and an inverter if AC power is needed. The system uses solar panels to collect energy that is stored in batteries and can be accessed as DC power or as AC power if the power is fed through an inverter.

Solar-powered generators come in various sizes and capacities. The larger the unit, the larger the battery pack that is required. Larger systems can provide more power but are less portable and more expensive. A small unit of 2 watts can be used to supply power for a radio, and is capable of recharging batteries for a laptop computer or cellular phone or other small electrical equipment. A small solar-powered unit is designed to be lightweight, and can be picked up easily, or carried as a backpack. If the need is to provide power for refrigeration, lighting, and water pumping, the system needs to be much larger, i.e., 100 watts. This mid-sized system can be moved easily in a car trunk. The larger unit of 1 to 2 kW is normally mounted on a trailer for easy transport and can supply power to an emergency shelter for a long period of time.

Portable solar systems can be sized to provide 100 percent of the load. They offer very low operating and maintenance costs but have high upfront costs. Some trailer-mounted solar systems come with an engine generator that can be used as backup during cloudy days when there is not enough sunshine to provide power to batteries. At some locations, the solar power may eliminate the need for engine generators, and at others, solar power can cut generator use by half. This helps lower the use of fuel, which is often a scare resource during disasters. The combination of a solar system and an engine generator will lower the upfront cost for a given load as the engine generator is sized to provide 25 to 75 percent of the load requirement, but it will ultimately involve a higher operating cost and fuel cost.

Features to consider when purchasing a portable solar-powered generator are cost, power features, and overall portability (i.e., weight, size, number of components). It is important to consider power features that meet the specific needs. For example, users need to consider the type of power the system provides (DC power only, or both DC and AC power), size of inverter included with the system, run times and re-charge periods for the battery, and ability to increase generating and storage capacity.

Several manufacturers offer pre-packaged solar-powered generators that include all components needed for an electric power system. Some manufacturers also offer special prices when several units are purchased at once. For example, SolarOne Solutions manufactures a portable solar-powered generator appropriate for disaster relief called the Harvester™ Solar-Electric Generator.[44] The Harvester™ is a mobile, micro-utility

[44] See www.solarone.net/Products/harvester_mobile.html

system mounted on a two-wheeled cart that can easily fit in the trunk of a car. It is designed for portability and easy assembly. The system can be easily set up in about half an hour. The system includes three basic sub-assemblies—solar module, platform, and power center. The solar module is 80 watts, expandable to 240 watts. The power center includes 15-amp PWM charge controller with LCD display, a 105 amp-hour sealed deep cycle battery, and a 110V/60Hz or 220V/50Hz truesine inverter (for AC models). The Harvester™ is available in three models—one to supply DC only, one to supply both 120AC and DC power, and one to supply 220AC and DC power. A Harvester™ unit with 240-watt solar panels to supply 220AC and DC power costs about US$4,985. Run times depend on type of appliances. The 80-watt solar will run a 26-watt light for about 48 hours or with 240-watt solar, it will run a 26-watt light in about 61 hours. The Harvester™ is appropriate for a smaller group of people, aide teams, communications, ad hoc schools, etc. Massive rescue and relief operations do require larger systems. The Harvester™ weighs about 170 pounds. With heavy duty wheels and a handle, it can be moved around easily by one person like a handtruck or dolly.

The PowerPod Systems by PowerPod Corporation[45] have been deployed in a wide range of climate conditions. The systems are available in several different capacities ranging from 100- to 2000-watt PV panels. A small unit (PowerPod P300/1400-12) with 100-watt PV panels, a 1400-watt inverter providing 12 VDC power and/or AC power is sufficient for small applications like lighting in a rescue tent, or for powering small communications equipment such as transceiver/walkie-talkie, cell phone charger, laptop for data entry/transmission, or perhaps an auxiliary water pumping system if necessary. A PowerPod B3000/4000-24 could be deployed for mid-range applications such as charging repeaters and communications equipment. This system provides 24 VDC power and 120 VAC power, with 4 to 6 PV panels (64-watt each) and a 4 kW inverter. The largest PowerPod System, SP2000B, can be placed at a high ground location as a gathering point for refugees, and to accommodate a larger scale support facility. The SP2000B has a 2-kilowatt solar array with roof/ground mounts for easy installation, and a 4000 watt sine wave inverter with 10,000-watt surge capability. All PowerPod systems can be customized to allow for different voltages and frequencies (50 Hz or 60 Hz, 120 VAC or 240 VAC). The SP2000B was installed at a medical clinic in Kenya to provide reliable power for the clinic's refrigeration of medical supplies, lighting, and a computer for storing patient records. The PowerPod systems come complete with solar panels, battery storage, controller, DC load center, and inverter. The current price for a P300/1400-12 is US$3,938; for a B3000/4000-24, US$20,375; and for a SP2000B, US$35,850.

Sundance Solar produces a 40-watt Solar Energy System with Xantrex 1500 backup power for emergencies. The total system weights about 85 lbs. and is fully integrated and ready to use. The system comes complete with a 40-watt BP 340U solar panel, the Xantrex XPower 1500, and the Sunguard 4 charge controller to prevent overcharging of the battery. The Xantrex XPower Powerpack 1500 is a portable power system that can

[45] www.powerpod.com

supply up to 1500 watts of household electricity – enough to run almost any electronic product or appliance that would be connected to a wall outlet at home. XPower Powerpack 1500 consists of a battery pack that stores 60 amp-hours of electrical energy, electronics that convert 12V from the battery pack to household power, an AC power panel that contains two standard outlets, and a DC power panel that is used to run 12V products. These components are packaged into a rugged "cart" with a removable waist handle that allows it to be wheeled from site to site over rough terrain.[46]

Hybrid Power Systems

Hybrid power systems that employ more than one technology are also available for disaster relief. The SP Hybrid™ 800 and 1000 watts manufactured by Sacred Power Corporation offer capabilities useful for disaster relief.[47] The SP Hybrid 800 is an 800-watt fixed array combined with either a 400-watt wind turbine or a 3.4 kW propane generator, which can provide AC power output ratings between 2.5 to 7 kWh depending on inverter type. The SP Hybrid 1000 is a system with 1000 watt peak of solar power and a 7000-watt propane generator. The systems are pre-assembled and ready to use. The systems cost about US$20,000.

Mobile Power Stations (MPS)® by SkyBuilt Power are another option for disaster relief needs.[48] MPS is a modular, containerized, mobile power system that can be set up in hours and is a complete power system prepackaged in a standard freight container that is easy to ship worldwide. The system can be any combination of solar/wind/batteries and micro-hydropower, and also can work with diesel or other fuel-based systems. This system provides more reliable power than fuel-based systems alone. The MPS can provide power from 3.5 kW to 150 kW. It can be remotely controlled. It can be used to provide emergency power for disaster relief or long-term power needs. In addition, once the MPS is deployed, the inside of the container can be used for other purposes such as self-powered, climate controlled storage, an emergency operations center for disaster relief teams, a mobile medical clinic, for border patrol operations, or a remote telecom power station.

Solar-Powered Battery Chargers

Batteries are used to power items such as hand-held radios, cellular phones, and small electric hand tools. Rechargeable batteries last about 8 hours, and alkaline batteries last 24 hours. Rescue teams can run out of battery power while on extended missions and thus may be unable to continue their work or communicate with people at their home stations. To resume work, they must return to their stations to charge batteries or have

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[46] http://store.sundancesolar.com

[47] www.sacredpowercorp.com

[48] See www.skybuilt.com

someone bring them new batteries. A better option is for the rescue team to carry a solar battery charger in a backpack and recharge batteries while continuing work in the field.

Solar battery chargers are available as units to charge common batteries including D, C, AA, or AAA size batteries and are also available as a 12V battery charger to supply power to notebook computers, satellite telephones, or electric hand tools, or to use as an independent power source for outdoor activities during emergencies or power outages. Most solar battery chargers have a built-in blocking diode to prevent reverse flow of electricity from fully charged batteries while sitting. They also may come with features such as a blinking charge indicator or built-in meter to display the strength of the current output from the solar panel and the time it will take to fully recharge the batteries.[49] The SunWize Portable Energy System, for example, can charge at five different voltages between 3 and 12 volts and weighs only 2.5 pounds.[50]

Another PV-battery charging option would be to equip a mobile unit with PV panels. It can be parked at a remote site to recharge an entire bank of cellular phones or radio battery packs simultaneously. Search cameras and high-tech listening devices used to locate trapped victims also operate on DC batteries, which could possibly be recharged using PV panels.[51]

Portable Solar Lighting

Flashlights are useful for providing light when no power is available. Regular flashlights need batteries that may be difficult to obtain during a disaster. Alkaline batteries need to be disposed of after about 24 hours of use, and create environmental problems. Rechargeable batteries are available to use with flashlights but they will not be usable if electricity is not available to recharge them. Solar-powered flashlights and solar-powered lanterns offer the benefits of no required fuels, no fumes, no spills, and no risk of fire or possible explosions. There is no need for external batteries, and thus there are no toxic lead-acid, cadmium or alkaline batteries to be disposed of that can pollute the environment. Because they do not release any carbon monoxide or sulfur dioxide, solar powered flashlights or lanterns can be used safely indoors or outside. A less than one-watt solar flashlight with a small battery can provide lighting for 8 to12 hours if fully charged, and will prove to be very useful while power is out and batteries are not available. A solar flashlight with an LED (light emitting diode) as the lighting source will provide thousands of lighting hours, has a much longer life span than regular light bulbs, and emits a brighter light. LEDs do not have a sensitive filament to break and withstand much abuse. LED flashlights are highly recommended for any preparedness plan because of their longevity and reliability. LED-based flashlights are very efficient,

[49] http://store.advancemart.com

[50] www.sunwize.com/products/pes.htm

[51] "Operation Fresh Start", a project of the National Center for Appropriate Technology, see http://freshstart.ncat.org/articles/enrgsyst.htm#pv

and thus can be used much longer on a single charge and are fully recharged in a shorter period of time.

Solar lanterns typically use a fluorescent or compact fluorescent bulb as a lighting source. The unit contains one or two electric bulbs, a battery, and a solar panel. The solar panel can be attached to the lantern or can be detachable. The size of battery, electric bulb, and the PV model determine the hours of operation. A lantern with a 3-watt solar panel, 6-volt / 4-amp-hour battery can operate continuously for 4 to 6 hours with a 6-watt bulb, or 3 to 5 hours when powering two 6-watt (12-watt) bulbs.

Solar-Powered Radios

It is important that in the event of a natural disaster or any emergency, rescue teams can communicate to request assistance, information or supplies, and that people can use radios to listen to government broadcasts for emergency warning or evacuation plans. Solar-powered shortwave radios, two-way radios or ham radios are widely available in various models and can provide vital services even when grid power is out and/or batteries are unobtainable.

Many AM/FM radios are designed to operate using several power sources including electricity, external batteries (i.e., AA batteries), or solar power (to play the radio directly or to charge the internal Ni-Mh batteries). The radios may also be charged with a hand crank generator. Some AM/FM radios are also shortwave radios that can pick up many international shortwave broadcasts anywhere in the world. Some models come with features such as a flashlight, compass, thermometer, clock, and sirens, which are all useful functions during disasters. One example is the Kaito radios which have been used by the U.S. and U.K. military.[52]

Two-way radios (or walkie-talkies) are very popular in normal situations to stay in touch while hunting or camping or taking separate cars on a road trip, and are very useful in emergency situations. There are many makes of two-way radios—ones with regular batteries, and ones with rechargeable batteries that can be charged with a solar-powered charger. Another good option for emergencies is to have solar-powered two-way radios in which the internal battery can be charged by itself, simply by placing the radio in the sunlight. The Sharper Image Solar Two-way Radio has a built-in solar charger that can recharge the battery pack that powers the radio. It has a transmission range of up to five miles with up to 12 hours of talk time on a full charge. It is a small size radio that measures only 7×2×1 inches and weighs only 5 oz.[53]

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[52] The product is manufactured by Kaito Electronic. Retailers for the products include, for example, Advancedmart (http://store.advancedmart.com).

[53] www.sharperimage.com

Solar-Powered Water Purification

Clean drinking water is in especially critical demand after disasters. Often, following disasters, water supply systems are destroyed, groundwater becomes contaminated, leaving communities in need of large quantities of bottled drinking water that often have to be transported from a distant supply. If electricity was available, it could run water purification systems to provide people with clean drinking water. With a solar-powered water purification system, communities can have clean drinking water even when grid power is not available and without relying on outside help to supply bottled water. Solar-powered water purification systems incorporate a multi-stage micro-filtration process and ultraviolet light treatment to kill biological pathogens (i.e., bacteria, viruses, and parasites), inorganic contaminants (i.e., dirt, sediments, total dissolved solids, etc.), and organic contaminants (i.e., volatile organic compounds, pesticide, benzene, etc.) to make safe, clean drinking water. Several solar-powered water purification models are manufactured and available commercially. As an example, SolarOne Solution manufactures a solar powered water purification system called Harvester™ Water Purification System that is portable, and can purify water from wells, ponds, streams or rainwater.[54] The unit is a complete system and fully assembled. It includes an 80-watt standard solar panel (expandable from 1 to 3 panels (240 watts) per system), 100 amp-hour sealed battery, filters, and a pump. The unit with a 1×80-watt solar panel can produce about 250 gallons of water per day. The unit with 3×80-watt (240 watts) solar panels can produce about 750 gallons per day. The Harvester water purification system weighs only 60 pounds.

Mobile MaxPure® by WorldWater & Solar Technology Corporation is more suitable for larger applications.[55] The Mobile MaxPure® unit is capable of purifying up to 30,000 gallons of potable water daily and can draw from both surface and well water sources. It can be powered by solar power alone (3.1 kW solar array), or in combination with an optional back-up generator such as diesel motors, electricity from batteries, or power from the grid. It is a self-contained, standalone unit that is equipped with a satellite-based communications system, and a 3 kW AC/DC pure sine wave inverter with 3000 amp-hour deep cycle maintenance-free AGM battery for emergency power needs. The unit can be trailer-mounted and towed into a disaster area by a pickup or an SUV, or can be folded into a 7-foot cube that will fit international shipping container specifications. The unit can be installed on a permanent, temporary or semi-permanent basis. Mobile MaxPure® provided approximately 350,000 gallons of clean, potable water and 2500 kWh of electricity used for emergency power for hurricane victims in Waveland, Mississippi, for an eight month period after Hurricane Katrina struck the United States' Gulf Coast in 2005. A unit of Mobile MaxPure® configured for disaster response costs about US$95,000.

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[54] www.solarone.net/Products/harvester_waterpurifier.html

[55] MillenniumKI, LLC is the primary distributor of the WorldWater & Solar Technology Corporation for humanitarian NGOs, see www.MillenniumKI.com

Solar-Powered Water Desalination

If the water source is high salinity seawater, a solar-powered desalinator can be used to separate and remove salts and other dissolved solids to make potable water. This is especially suitable for producing potable water after disasters in coastal areas. Most desalination processes use reverse osmosis technology. Solar-powered desalination systems work by using solar electric panels to convert solar radiation to electric power. The desalinator then uses this electric power for reverse osmosis to convert seawater into drinking water. Solar-powered desalinators are available for various applications, and for water conditions ranging from high salinity seawater to low-salinity brackish water. Some models are very compact and portable enabling them to be carried easily by two people. They can be set up in minutes, making them suitable for use in emergency response situations. Blue Spring Corporation[56] manufactures various solar-powered desalinators that are compact in size and can produce fresh water in quantities ranging from 300 liters to 6,800 liters per day depending on the model. The Blue Spring SW-S Series is designed to desalinate high salinity seawater and the EC-S Series is designed for low-salinity brackish water (handles limited salinity up to 3,000 mg/l). The systems produce fresh water that surpasses drinking water standards established by the World Health Organization. The systems can also be coupled with storage battery packs, providing for three modes of operation: solar power only, battery power only, or solar/battery power simultaneously. The battery-only operation is particularly useful when small amounts of fresh water are needed for emergencies at night.

The Spectra Solar Cube, produced by Spectra Watermakers, Inc.,[57] can purify and desalinate water from almost any source using integrated photovoltaic solar panels and a wind-powered generator. The Solar Cube can provide both drinking water and electricity for disaster relief. Each system is sold complete and ready to deploy in a matter of hours. No building, infrastructure or fuel is required. The Solar Cube is available in three models (for use with saline water and non-saline water sources) producing between 3,500 liters and 15,000 liters of fresh water per day. They were used to provide drinking water and electrical power to several villages in Pakistan after the major earthquake in 2005. The Solar Cube ranges in price from US$38,000 to US$80,000, depending on the model.

Solar-Powered Water Pumping

Electricity can be out for a long period of time in the aftermath of a disaster. With solar-powered water pumps, water can continue to be pumped as it is needed at a farm, ranch, or construction site even during blackout periods. Solar water pumps can be a stand-alone system or work in conjunction with grid power. Some portable solar pumping systems do not require batteries but work directly off the power supplied by solar panels. With grid power, solar power will run the pump during the day with sunshine, helping to lower electricity costs. On a cloudy day, grid power will supplement solar power in

[56] www.bluspr.com

[57] www.spectrawatermakers.com

running the water pump. Solar powered water pumps are available as portable units or mobile units on a trailer.

Solar Power for Transportation Aids and Warning Signals

Safety functions on roads are still required even when power is out following a disaster. Solar systems can be used to power all kinds of transportation aids and warning signals. Solar is being used more and more frequently to power road markers, highway message boards, traffic arrows, flashing barricade lightings, school-zone flashers, and other warning signals—both during disasters when grid power is unavailable and for day-to-day use.

Highway message boards are useful during disasters as well as during normal times to communicate traffic information to motorists and to alert motorists to radio advisory systems. These message boards used to be powered by diesel generators. Now, they are more often powered by solar. Solar-powered message boards cost less than diesel powered message boards because they need less maintenance, require no fuel and last longer. Many solar message boards employ a 425-watt array, which is often not wider than the sign itself and can be tilted or rotated to face south for maximum battery charging. Many solar-powered message boards also come with cellular phones that enable operators to re-program messages remotely.[58]

School zone flashers can be run appropriately by solar power. Flashing lights alert drivers to reduce speed or to beware of crosswalks. Solar school zone flashers are typically pre-assembled and ready to install. They can be installed quickly and can be moved easily if traffic conditions change. Usually, the system is simple, consisting of a PV panel (rated between 60 and 85 Wp) mounted above the top flashing beacon, a deep-cycle, 12V battery (in a weatherproof enclosure beneath the sign), a charge controller, and the electric circuitry needed to activate the sign at desired hours.[59]

Road markers or traffic arrows direct drivers to follow appropriate roads for their safety. These signs normally use LED lamps as lighting sources to provide bright light and to increase the light source life span. They can be set for steady or flashing lights.

Solar power is appropriate for such applications since these traffic signs need to be mobile and thus a utility connection is not practical. Using diesel-powered generators is more expensive because they require refueling and maintenance.

Portable PV-Powered Repeaters

PV-powered repeaters are useful as they can help extend the range of communications beyond hand-held radios. Some new models can effectively transmit and receive in the

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[58] www.gpp.org/energy_ideas/EI.0296/EI.0296.04.html

[59] www.gpp.org/energy_ideas/EI.0296/EI.0296.04.html

range of up to 1000 feet. As power lines and all communication links are often destroyed during a disaster, portable PV-powered repeaters will enable police and emergency crews to communicate and coordinate emergency tasks. Portable PV-powered repeaters are appropriate for such use because they are small, easy to transport to remote areas, and can be left alone indefinitely. They can supply a small load requirement more efficiently than can an oversized generator, and they do not require regular refueling.

Solar-Powered Refrigerators

Solar-powered refrigerators are compression refrigerators that are powered by 12 or 24V storage batteries that can be charged by PV panels. Solar-powered refrigerators are appropriate for clinics in remote areas with no electric power, locations with unreliable power or for use during disasters when power outages inevitably occur.

Kyocera Solar, Inc.[60] has developed a solar-powered vaccine refrigerator/icepack freezer system—VaccPak XL series—that uses solar technology advantages, like thermal storage, to extend battery life and capacity and to increase storage time, while ensuring stable operating temperatures. The products meet WHO/UNICEF performance standard (E3/RF.4). The VaccPakXL2100 is designed for small clinics with vaccine storage capacity of 21 liters and icepack storage capacity of 24 packs (0.4 liter). The VaccPakXL6000 is designed for larger clinics with vaccine storage capacity of 60 liters and icepack storage capacity of 32 packs (0.6 liter). At 32˚C, the holdover time is 21.7 hours for the XL2100 and 17 hours for the XL6000.

E-Solar Pty Ltd[61] in Australia supplies larger sized solar powered refrigerators with capacities of 110 liters, 160 liters and 220 liters. These refrigerators weigh 25 kilograms (kg), 36 kg or 44 kg and are powered by either 160-watt or 240-watt solar modules with 200 amp-hour battery banks.

5.2 Village Power Technologies for Community Reconstruction

Energy efficiency should be the initial focus when reconstructing communities. If less energy is needed under normal circumstances, communities will be less energy dependent and more resilient when electricity is not available during disasters. Energy savings in buildings can begin with the building envelope, insulation, and use of energy-efficient windows, passive solar, and good ventilation to make buildings more comfortable and to minimize the need for cooling or heating. In addition, using energy-efficient appliances and energy-efficient lighting will further lower energy requirements and thus needed energy supplies.

Village power technologies like standalone solar power systems, off-grid wind generators, hybrid systems (such as wind/solar/diesel/battery), hydropower, and biomass,

[60] www.kyocerasolar.com

[61] www.esolar.com.au

as well as distributed generation, which uses several small sources of energy on site to supplement grid power, should be evaluated for use in community reconstruction. In many circumstances, these technologies could prove to be more cost-effective than conventional fuels alone. These technologies will make communities less dependent on imported fuels while increasing disaster resilience. Village power technologies will provide clean energy to communities during normal times and will ensure that they have power during disasters when grid power is not available. This section discusses village power technologies that governments should consider using when reconstructing communities after disasters as well as in new community development.

Micro-hydropower

When there is free-flowing water, micro-hydro generators will be the most economical option for providing electricity for people in rural areas. Micro-hydro systems can produce many times more power than solar or wind for the same capital investment. Since water flows day and night, a micro-hydro system requires less battery storage than other technologies. Hydropower is a very clean source of energy. The energy availability is predictable. There is no fuel requirement. Operating cost is low. The system can last for 50 years without major new investments. Also, given a reasonable head, power is normally available on demand.

By definition, micro-hydropower refers to a system with a power output less than 100 kW that is more suitable for power demands at a village level. Micro-hydropower has the advantages of hydropower with decentralized power generation without the disadvantage of large-scale installation, costly distribution of energy, and without large environmental impacts.

Hydro systems are very site specific. Head and flow are the factors contributing to amount of power production. Head is the change in elevation of water from a high level to a lower level. This change in elevation supplies the pressure, which drives the turbine. Flow is the volume of water per unit of time available to the turbine. Flow is usually limited by the size of the creek. Flow varies seasonally and may vary along a creek's length if tributaries flow into it. The amount of electricity produced is directly related to the head and flow. If the head or flow is increased, the power output increases proportionally.

Different turbines and generators are available for selection based on water head and flow rate. A turbine can be up to a couple of kilometers away from where the power is being used and still be cost effective. Hydro turbines convert water pressure into mechanical shaft power that can be used to drive an electricity generator, a grinding mill or other useful devices. The generators produce AC electricity that can be used directly to power most household appliances.

Hydropower has some disadvantages, however. It is a site-specific technology. Sites that are well suited for using hydropower technology may not be close to where the power can be utilized economically. In addition, a given hydropower site always has a maximum useful output that is not expandable, which therefore limits how activities in the community can be expanded. In addition, seasonal river flows often vary significantly, which makes power output varying seasonally.

Wind Power

Wind power is another option for providing electricity to remote locations. Wind power systems can be operated interactively with the grid or as standalone installations for off-grid power. They can be added to an existing diesel power system to make a hybrid system that can provide reliable power all year. Most small turbines have very few moving parts and do not require any regular maintenance. They are designed for a long life (up to 20 years) and operate completely automatically. In general most wind turbines begin to produce electricity at wind speeds of about 4 meters per second (9 miles per hour). As wind speeds increase, the amount of electricity generated increases exponentially. At good wind energy sites, a turbine will normally operate at approximately 35 percent of its total possible capacity when averaged over a year.

Wind turbines are normally categorized as utility scale, industrial scale or residential scale. Utility-scale wind turbines refer to large turbines, e.g., 900 kW to 2 megawatts (MW) per turbine. They are typically installed as a large wind farm, which may range in size from a few megawatts to hundreds of megawatts. They are intended to generate bulk energy, but can also be installed in small numbers for distributed generation. Industrial-scale wind turbines are medium sized turbines between 50 kW to 250 kW and are typically used in light commercial/industrial and village power applications. Residential-scale turbines are micro- and small-scale turbines, e.g., 400 watts to 50 kW, and are normally used for homes, telecommunications, battery charging, or water pumping.[62]

Small standalone wind turbines are often far less expensive than extending a power line in remote areas. As wind is an intermittent resource, standalone wind-power systems need battery storage to deliver 24-hour utility grade power and to provide power when the utility grid goes down.

Clusters of small wind turbines can be connected to a utility power grid for distributed generation. Wind systems that are integrated with grids will give consumers a hedge against power fluctuations and help reduce grid demand during peak loads. Wind power plants are reliable. Even if several turbines in a plant are down for maintenance, the flow of electricity into the grid continues uninterrupted so long as the wind is blowing. If the grid-connected wind power system is owned by an individual, the extra electricity that is produced above what is needed may be sold back to the grid through a net metering procedure if allowed by the local utility. A wind power grid-connected system with battery backup will continue to provide power even when power from the grid is not available.

[62] http://www.powernaturally.org/Programs/Wind/toolkit/9_windturbinetech.pdf

A small diesel power plant may be a common option in many economies for supplying electricity to remote rural areas because a small diesel power plant has low start-up costs and a short construction time. However, delivering diesel to remote rural areas to run these power plants incurs high transportation costs in addition to high fuel costs. If wind resources are available in the area, adding a wind turbine to the existing diesel generator system will lower the amount of diesel used and lower generating costs.

Solar Power

Grid-based power systems are the most economic option for large concentrations of households or productive loads. Grid systems require large fixed-cost investments in power plants, and in transmission and distribution lines, and thus require economies of scale. Where households or demand sources are located far from the existing grids, or have too small a load, standalone solar power systems can be the least expensive option for delivering electricity services. In areas with sparsely located households, a rural electrification program that provides a solar home system to each household can be an effective choice. Solar home systems for rural electrification can also be a temporary electricity solution. As electricity demand in an area increases enough to warrant a cost-effective grid connection, the used solar systems can be sold if owned by the households, or transferred by the utility for use in another location.

Standalone PV systems can be used in numerous applications including:

- Electrification of remote sites far from utility distribution networks such as rural communities, island villages, park ranger sites, visitor centers in parks, vacation cabins, campgrounds, remote health clinics and research facilities, military test areas, etc.
- Lighting, especially, low power DC lighting such as low pressure sodium and fluorescent lights that provide lighting for parking lots, billboards, public facilities, and caboose lighting for trains.
- Communications systems that require power at repeater stations at high elevations where power lines are not commonly found and transport of conventional generator fuels would be difficult and costly.
- Signs and signals in remote areas that are not connected to the utility grid such as highway information signs, flashing signals, navigational warning signals, railroad signals, buoys, and lighthouses.
- Remote monitoring at temporary sites such as those that monitor scientific research, meteorological information, highway/traffic conditions, irrigation control or seismic recording.
- Water purification to power an ultraviolet light disinfecting process.
- Water pumping to provide water for farming, livestock, campgrounds or other human settlements.
- Refrigeration for remote or mobile storage of medicines and vaccines.

A solar power system can be installed in conjunction with diesel generation and/or wind generators with battery backup to meet power requirement in remote areas. Hybrid systems of wind and solar are a good combination and will increase system reliability, because PV power generation can be used during the day when it is sunny and the wind power generator can be used at night when the sun is down. A diesel-powered generator can also be used as a backup with a wind generator and/or solar power for continuous power use.

When grid power is available, PV systems are relatively expensive. However, they are an option when it is necessary to "shave" an existing power demand that is approaching overload capacity. Businesses that are vulnerable to power outages may consider supplementing grid power with on-site PV electricity and battery backup. This will provide emergency power to insulate the businesses against costly damage from grid disruptions. For a community with a grid-connected system, a small PV system with battery backup may be installed at a community center as an emergency power source since the community center could be a gathering place for residents during emergencies. A grid-connected system with a PV system and battery backup will continue to provide power during grid power outages, and will make communities more resilient during a disaster. In most economies, excess power generated on site can be sold back to utilities through net metering.

More specific applications of solar energy that governments may consider using in post-disaster reconstruction are discussed below.

Solar for Marine Applications

PV panels can be used in many marine applications, including to power coast guard navigation buoys, lighthouses, and warning beacons. This equipment needs only a small amount of power, but it must be reliable, which makes PV power appropriate. Each buoy and lighting beacon uses a single PV module to supply 6 to 9 watts of intermittent power. The life-cycle costs of energy supplied by disposable batteries have proven to be more expensive than using PV to charge rechargeable batteries on site. Disposable batteries also require replacement every two years while PV-powered rechargeable batteries only need replacement every ten years. Since 1984, the U.S. Coast Guard has converted 15,650 of its navigational buoys and lighting beacons from disposable batteries to PV-powered rechargeable batteries, and has saved an estimated US$2 million a year in maintenance costs (including battery replacement and disposal) and US$3 million in battery costs. These savings will continue to increase, as current battery disposal costs continue to rise. Several lighthouses in the New England region of the U.S. that previously ran on either diesel or electricity from underwater cables have been retrofitted to use PV power. Diesel generators require intensive maintenance (every four months) and high fuel costs, while PV systems require maintenance only twice a year, battery replacement every ten years, and PV panel replacement every 20 years.[63]

[63] www.gpp.org/energy_ideas/EI.0296/EI.0296.04.html

PV can also be used to power railroad signals and aircraft warning lights. These transportation warning signals will continue to function and provide public safety even if grid power is not available during disasters or other power outages.

Solar-Powered Streetlights

Solar streetlights require no trenching, pavement excavation, wiring or metering, and require minimal maintenance. Solar streetlights can provide lighting at security stations, warehouses, and parking lots. They are ideal for remote locations where the cost of extending a grid-connected line is prohibitive. A solar streetlight unit is self-contained, consisting of PV panels to collect energy, a deep-cycle, maintenance-free, gel-cell battery to store energy during the day and power the lights at night, and a charge controller to regulate battery charging. The battery can store enough energy to run the lights consecutively for 5 to 7 days without sunshine. Solar lights will require no more maintenance than replacing fluorescent bulbs every 2.5 years and replacing batteries every 5 to 7 years.

Solar Outdoor Lighting, Inc. manufactures solar powered streetlights.[64] The company's SL-Hurricane Series are certified to meet or exceed ASCE-7-05 specifications for 150 miles per hour (mph), Exposure D extreme wind event. All 33 solar streetlights from Solar Outdoor Lighting that were installed in a Miami, Florida subdivision withstood the 165 mph winds of Hurricane Andrew that hit south Florida in 1992, and provided light in the neighborhood when surrounding grid-connected lights were down for two weeks after the hurricane. The SL Series is available for both flat surface poles (SL-HF Series) and for round surface poles (SL-HR Series) with power ranging from 160 to 240 watts.

Some cities in the U.S. have installed PV-powered lights along bike paths, walking paths, and parking lots. These cities saved money as PV-powered lights had a lower upfront cost than the installation of underground utility services, and eliminated the expense of grid electricity. The State of Hawaii installed a hybrid system of PV- and wind-powered lights along the parking lot at Hanuama Bay. The system has provided lighting in the parking lot for the past four years and the manager of the Hanuama Bay facilities has been very happy with light fixtures' performance. PV-lit bus shelters can also be found in several places in the U.S.

Solar Systems for Gas Pumping

Use of PV systems to power gas pumps at gas stations will solve the problem of not being able to run gas pumps during power outages. This would enable emergency vehicles to refuel and run when grid electricity is unavailable after a disaster. Japan is the first economy that has equipped PV systems to power gas station pumps. The British Petroleum (BP) company announced its first 'went solar' retail sites in 1989 with a project to incorporate solar power into 200 of its retail sites in ten countries around the world. The 200th site was completed at the end of 2000. All these sites have PV arrays

[64] www.solarlighting.com

installed on top of a conventional forecourt canopy. In 2001, BP announced the second project called Project Sunflower that uses solar panels to make up the roof of the canopy itself in all new or significantly remodeled BP service stations worldwide. The canopy is built using translucent photovoltaic modules made of thin silicon films deposited onto glass. The canopies come in two sizes depending on the number of fueling positions. The smaller one is constructed with 434 PV modules, the larger one with 560 PV modules. Each module will produce a nominal 40 watts DC. The system is fitted with several inverters and will typically produce 15 kW AC power, sufficient to power three to four houses. These systems are net-metered into the utility grid so that any extra electricity generated will be fed into the grid for sale. Project Sunflower has placed a total of 3.5 MW of solar power at BP service stations around the world.[65]

Solar-Powered Emergency Call Boxes

PV panels can be used to power emergency cell phone call boxes along highways, as cell phones need only a small amount of energy to operate and require reliable power in remote locations. Emergency call boxes benefit motorists greatly, enabling them to call for help when cars break down or have flat tires, or to report a road hazard or traffic accident. A typical PV-powered emergency call box consists of a two-way cellular telephone, an 8 or 10-watt PV panel, a sealed rechargeable lead-acid battery, and an antenna. A PV panel powers the phone during daylight hours and charges batteries to power the phone for night use. It requires a couple of hours to install each box, and is much easier and cheaper than linking each call box to the grid.

Many states in the U.S. now use PV emergency call boxes, including California, Arizona, Colorado, Maryland, Minnesota, Ohio, and Texas. California set up the CalSAFE (California Service Authority for Freeway Emergency) program in 1986.[66] Organized through the California Department of Transportation, a total of 17 CalSAFEs have been formed, covering 31 of California's 58 counties. Forming a CalSAFE gives a county the authority to levy and collect a $1 fee on all vehicles registered within that county. The funds raised in a particular county may only be used to finance a motorist aid system within that county. The roadside call box is the main component of a motorist aid system. As part of CalSAFE, over 15,000 PV-powered emergency call boxes have been installed along California highways covering over 6,300 miles of highway in 26 counties. The call boxes are located on the right hand shoulders of roadways. The distance between call boxes ranges from 1/4 mile (on heavily traveled urban freeways) to 2 miles (on more lightly traveled rural roadways). A call box is installed in each direction on highways with median strips or more than four traffic lanes. Each county is responsible for installing and maintaining its own call boxes. Maintenance crews visit each call box twice a year to clean the PV panels to ensure maximum efficiency and to replace any worn out batteries.

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65 www.greenenergyohio.org/page.cfm?pageID=181

66 http://www.calsafe.org/info.html

To use a call box, motorists need only open the front of the unit and, depending on the model, simply pick up the phone or press a button. Calls from call boxes will be connected directly to the California Highway Patrol (CHP) communication center. Since the call is coded, the CHP operator automatically knows the location of the call box being used. This means that the call box user does not need to know his or her location to receive assistance. Upon receiving the call, the CHP operator will dispatch appropriate assistance or connect the caller to a desired phone number for roadside assistance. Use of the call box is free, but call box users are responsible for paying towing and other roadside assistance charges.

PV call boxes can also be equipped with small computers, sensors, and video cameras so authorities can assess where roads are slippery or impassable due to poor visibility. This information can help reduce weather-related highway accidents.[67]

Solar-Powered Remote Monitoring Applications

Solar power is used in many remote monitoring applications. Remote PV-powered sensors, data loggers, and information transmitters can send data continuously to central offices for use in flood, drought or forest fire forecasting, or to convey information about weather patterns, water quality or highway conditions.

A compact standalone PV power system has been designed and built to run an air sampler for environmental monitoring at a test site in Nevada, U.S. The air-monitoring systems are installed in several remote sites where radioactive fallout was deposited by past nuclear tests. The air sampling is conducted continuously to measure concentrations of radioactivity in airborne particles to assess whether air is in compliance with U.S. federal regulations.[68]

Solar-Powered Tsunami Warning and Notification Systems[69]

Sirens are one of the many types of warning notification systems. Sirens are often used because they can cover wide areas—populated or isolated. Sirens can be activated by remote or local controls. They require low maintenance if tested regularly. Various versions of sirens are available in both electro-mechanical and electronic types relying either on AC power of 120 volt up to 440 volt or low-voltage storage batteries. The siren systems that rely on AC line power are vulnerable to power outages and electrical irregularities, particularly those caused by lightning strikes that can damage siren unit controls. Lightning can decommission the entire siren unit even if protection devices are installed. Siren systems that operate on low-voltage storage batteries with the battery

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[67] www.gpp.org/energy_ideas/EI.0296/EI.0296.04.html

[68] L.Sanidad, et.al., "Field Tests of a PV-Powered Air Monitoring System," Journal of Solar Energy Engineering, May 2003, Vol. 125, pp 203-206.

[69] Tsunami Warning Systems and Procedures, Oregon Department of Geology and Mineral Industries, Special Paper 35.

charge maintained by AC power have their siren controls and equipment better protected. However, the ideal protection for siren units and their controls is to use a solar power charger to charge the battery system and have no connection to AC power lines even for charging the battery power supply. Current prices of solar equipment are very competitive with the costs of equipping alarm system stations with AC power.

It is important to recognize that the success of a battery power supply system depends on the selection of proper batteries for the intended use. The need for sirens in one community may differ significantly from that of another community. A community with a heavily populated tsunami inundation zone may need to use its alarm system several times during an emergency. A community without extensive exposure to tsunami hazards might anticipate only a brief use of sirens. The capacity of battery-powered systems required by these two communities would differ significantly. The type of battery is also very important. Experience in the U.S. shows that batteries for wide-area alarm systems should be robust deep discharge, uninterrupted power supply (UPS), 6-volt batteries rather than half as many 12-volt batteries as this incurs less wear and tear on battery plates. While discharging to power the siren, the load is also spread over significantly more plate surface in this scheme than it would be with half as many 12-volt batteries. Service life of the 12-volt batteries in this circumstance can be extremely short due to their thin plates buckling from the heat generated while powering the siren. For a siren unit that is driven directly by AC power but is equipped with backup batteries in case of AC loss, the batteries' life span will be shortened if they are not used regularly. Backup batteries in siren units need a proper testing routine to ensure that they can provide adequate backup for emergency activation.[70]

An electronic siren station was established at Cannon Beach in Oregon. The unit is a Whelen WS2000-16 that includes a public address component. This unit is comprised of sixteen re-entrant speakers and four speakers aimed at each compass quadrant. The effective range is approximately 2,400 feet in each direction. Each station operates on 24 VDC supplied by four 6 VDC deep cycle storage batteries maintained by a solar charger entirely independent of commercial grid power.

Biogas Technology

If a community has sufficient livestock, biogas technology can be used to convert livestock waste to gas. Biogas is created by decomposing organic materials (solid and/or liquid) by anaerobic digestion. The digestion process takes place in a warmed, sealed, airless container (the digester) that creates the ideal oxygen-free conditions for the bacteria to ferment the organic material. A community can make an inexpensive, easy-to-install digester using a polyethylene tube.[71] The digester decomposes organic waste

[70] For more information on sirens, see www.warningsirens.org, www.warningsirens.com, www.airraidsirens.com, and www.sirensystems.com

[71] For information on how to make a simple plastic biodigester, see www.fao.org/WAICENT/FAOINFO/AGRICULT/AGA/AGAP/FRG/Recycle/biodig/manual.htm, and http://journeytoforever.org/biofuel_library/MethaneDigesters/MD6.html

like poultry waste, cow dung, pig manure, or any agricultural residue to produce biogas, which is composed mainly of methane and carbon dioxide. The product will be gas that the community can use for cooking and lighting. If sufficient feedstock is available to produce enough biogas, it can be used as fuel in reciprocating engines or in a micro-turbine to power a community electricity generator. Most solids not converted into methane settle out in the digester as a liquid sludge. This sludge contains elements such as nitrogen, phosphorus, and potassium that are essential to plants, and thus is a good organic fertilizer for community crops and can replace synthetic fertilizers that pollute the environment.

Anaerobic digestion can be done on a variety of scales, either on-site, using wastes produced on a single farm, or as a community-based project run cooperatively by several farmers that supply the digester with feedstock from several sources.

Transforming animal waste to biogas helps reduce problems with waste management, reduces pathogens and weed seeds, reduces seepage and runoff, and enhances community and health sanitation. It is estimated that a single cow can emit 100 to 200 liters of methane per day, not including the methane that continues to be generated as bacteria break down the mounds of manure.[72] This naturally occurring methane is a potent greenhouse gas that contributes to global warming. Capturing this methane in a biogas digester and transforming it to useful energy helps reduce the release of greenhouse gas into the atmosphere. Producing energy from local resources, instead of relying totally on expensive, conventional fuel from remote sources, offers the community savings and increases the sustainability of a rural community.

[72] http://sfgate.com/cgi-bin/article.cgi?f=/c/a/2004/05/14/BAGJG6LG3R15.DTL

Chapter 6

Recommendations to Increase the Utilization of Village Power Technologies

This chapter presents recommendations that will help promote greater use of village power technologies in disaster response and reconstruction. Because the nature of problems preventing the adoption of village power technologies for disaster response and reconstruction are somewhat different, the recommendations are presented separately.

6.1 Recommendations to Increase the Utilization of Village Power Technologies in Disaster Response

In emergency responses, advanced planning and fast deployment are critical as there is no time to spare. This is even more important if "new" technologies are being used. The obstacles that prevent adopting village power technologies for disaster response are generally associated with lack of advanced planning and knowledge of the technologies. Based on interviews with government officials and parties involved with disaster relief in the three affected economies, the main obstacles preventing greater use of village power technologies for disaster relief in the last Asian tsunami were (1) high initial cost of technology, (2) lack of available funds for the purchase of village power technologies, (3) lack of knowledge about the technologies, and (4) lack of knowledge of where to purchase the technologies. This section presents recommendations to reduce these obstacles.

Advanced Planning and Coordination

Disaster management programs and emergency plans are established in most economies. However, village power technologies are rarely included in these plans. As a result, funds are not allocated for technology acquisitions, so the technologies are not purchased or ready for deployment when needed. To ensure power availability for disaster relief efforts in the future, village power technologies need to be included in the emergency energy plans, and technologies need to be obtained in advance so they can be fully implemented during emergencies when they are most needed.

Most economies have designated government organizations responsible for emergency relief. In addition to government agencies, most economies also have private organizations sponsored by private clubs, large corporations or religious groups that will work as volunteers to bring in their own expertise and resources to help victims following a disaster. These organizations can play a major part in assisting governments during devastating disasters as was shown in the last Asian tsunami. Information about village power technologies should also be conveyed to these organizations so they will be included in their plans. The government should work with these groups on technology acquisition and training for proper use of these technologies.

Good coordination among all agencies responsible for emergency response is critical. An important aspect of this coordination is regularly scheduled drills during which all parties test their ability to communicate and work in a coordinated and timely fashion. Experience has shown that different agencies are often not able to communicate with each other during emergencies because communication equipment is incompatible. Thus the key to proper communication is to coordinate the purchase of compatible equipment prior to emergencies when it is actually needed.

Appropriate Technologies

Manufacturers should offer complete, prepackaged systems of renewable energy equipment that is ready to use for disaster response. Rescue teams should buy a complete package of the needed technology, rather than separate components requiring assembly as this may lead, for example, to discovering that batteries in stock are not the right type or size for the system.

Village power technologies for disaster response should be designed for fast and focused deployment. Ready-to-use, standalone systems designed for individual applications are most effective for response and recovery. For example, a small PV unit may be assigned for battery and cell phone charging. Another PV system may be set up to provide power for vaccine refrigeration, while a larger system would be prepared to provide electricity for lighting at the rescue tent.

An economy should prepare a list of effective disaster response equipment offered by various manufacturers and make it available to the public. The equipment on the list should first be tested and then certified to ensure that the equipment is appropriate for its intended use and works properly as specified by manufacturers. Consumers of such equipment, including government agencies, emergency management teams, local state authorities or private volunteer organizations, may not have the background to fully understand technical specifications of this technically advanced equipment. Having standards and certifications of the product guaranteed by the government, will give users confidence that the equipment purchased will work as specified by manufacturers, and therefore make it easier for them to select and purchase this equipment. APEC has currently funded a renewable energy products database project that provides lists of renewable energy products available in the APEC member economies.[73] Several products in the database are appropriate for use in disaster response. Governments and concerned parties can consult the database and contact manufacturers to obtain the products. The products in this database are, however, not certified or tested to guarantee their quality.

[73] APEC 21st Century Renewable Energy Development Initiative (Collaborative VI): Renewable Energy Products Database: Paving the Way for Deployment of Renewable Energy, see www.egnret.ewg.apec.org or www.technologydevelopmentpartners.org/apecdb/default.htm

Identify Potential Suppliers

One obstacle to utilizing village power technologies in the 2004 tsunami emergency response was that the governments and rescue organizations did not know where to obtain the products. After large-scale disasters, donations from various organizations may come in to support emergency operations. However, the rescue organizations will not have time to purchase new equipment and will end up using what they know and what they have in stock. For large solar-powered generators, the manufacturers often make them to order, on a first-come, first-serve basis, so it may take eight to ten weeks to deliver a unit after ordering. The equipment for disaster response needs to be ordered and obtained in advance. Governments should not wait until after a disaster occurs to obtain these products.

Many manufacturers offer good discounted prices for bulk purchases. If APEC economies could work together to coordinate their purchases, it is likely that significant cost reductions could be obtained.

Governments may set up an agency in their economies to facilitate purchases of renewable energy products for disaster response by government agencies and other concerned parties involved in disaster management. A similar practice has been established in the U.S. by a government organization called the U.S. General Services Administration (GSA),[74] the federal government's agency established to assist U.S. federal agencies with acquiring supplies and equipment. The GSA has set up a system called the GSA Advantage® to provide online shopping and ordering for U.S. federal purchasers. Over a million commercial products and services are listed and can be purchased through the GSA Advantage®. A purchaser can sort products by prices, part numbers, product names, manufacturers, contractors, or contract number. U.S. federal purchasers can use functions on GSA Global Supply to order products for global delivery and can be assured that the products will be in compliance with the U.S. government acquisition policies. GSA also provides full accountability from order placement through delivery and billing. Anyone can search for products and services on GSA Advantage® without registering for a user ID and password. However, only a federal government employee with a government purchase charge card or a GSA Activity Address Code can buy through GSA Advantage®. Federal buyers may request information, or obtain quotes and proposals for services or large quantity purchases through this system. A contractor can use this information to submit an offer in response to a GSA solicitation. This is useful as GSA awards contracts to companies that offer commercial items at reasonable prices that fall within descriptions in the GSA schedule solicitation.

GSA Advantage® includes a category of "Disaster Relief" to assist U.S. federal agencies acquiring supplies and equipment to support disaster relief and emergency preparedness.[75] In the Disaster Relief section, both supplies and services are listed.

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[74] www.gsa.gov

[75] www.gsa.gov/disasterrelief

Disaster Relief supplies include, for example, emergency and rescue equipment (i.e., fire fighting equipment, life vests, emergency lighting, etc), cleanup supplies (i.e., disinfectants, water treatments, waste containers, etc.), medical supplies (i.e., first aid kits, resuscitation products, body bags, etc.), vehicles, heavy equipment (i.e., backhoes, front end loaders, earth moving machinery, light trucks, etc.), and temporary housing and shelter (i.e., prefabricated shelters, decontamination shelters, sleeping bags, etc.). These items are all important and commonly needed for disaster relief. However, village power technology products that could also provide useful applications to disaster relief crews are not listed widely on the GSA website. Under electronic/power requirement category of Disaster Relief, only solar generators (mainly solar grid tied systems) and wind generators are listed. The main products for power production are diesel and gas generators. Emergency lighting under emergency and rescue category lists a few solar products including solar radios, solar flashlights, solar streetlights, solar lanterns, and solar flashing beacon lights. More renewable energy products for disaster relief should be added to the GSA website.

Training on Appropriate Technology

Solar energy could power many of the tools and equipment that support emergency operations. However, there is still a lack of understanding by emergency management personnel of solar energy applications and the conditions under which it is preferable to conventional technologies. Information about village power technologies that are useful for these tasks needs to be made available, and education needs to be provided to the authorities responsible for disaster response.

Rescue workers need to be trained in the proper use of the village power systems before the disaster occurs, as they will not be in the proper frame of mind to learn new technologies after disasters when they are so busy with disaster response activities.

Local research institutes, engineering societies or universities knowledgeable about renewable energy applications for disaster relief should organize training and workshops to educate emergency management teams and rescue workers about village power technologies appropriate for disaster response. Many organizations in the U.S. have conducted training and workshops on renewable energy and solar energy. For example, the Florida Solar Energy Center[76] has offered workshops that apply PV to disaster situations. The workshops cover topics such as impacts of different kinds of disasters, emergency management plans and operations, PV and other renewable energy applications, maintenance and reliability, disaster resistant communities, how to fit PV into specific needs and operations, and hands-on equipment demonstrations.[77]

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[76] www.fsec.ucf.edu

[77] William Young, "Problems and Solutions: Training Disaster Organizations on the Use of PV," Presented at ASES 2003, Florida Solar Energy Center, Publication Number FSEC-PF-371-03.

As another example, the North Carolina Solar Center (NCSC)[78] has offered an education program for professionals who wish to gain a higher level of knowledge and hands-on training in renewable energy technologies and sustainable building practices. The Renewable Energy Technologies Diploma Series at NCSC offers interdisciplinary training in solar thermal, photovoltaics, wind, residential green buildings, and biomass and biofuel technologies, as well as in business case studies, federal and state policies, and regularly features other renewable technologies such as geothermal or micro-hydro.

If portable solar generators can be assembled locally, it would lower the costs significantly. The Long Branch Environmental Education Center (LBEE),[79] a private, non-profit educational organization in North Carolina, has conducted a workshop series to train individuals in the design and hands-on assembly of 123-watt portable solar generators. The first workshop held in April 16, 2005 was an effort to develop a portable solar generator donation project to help earthquake and tsunami survivors in Southeast Asia and to raise awareness and funds for the donation of 1,000 portable solar generators to selected international aid organizations working to help earthquake and tsunami survivors. The workshop assembled a system that included one 123-watt photovoltaic module, two 200 amp-hour gel-cell batteries for backup storage, a 10-amp solar charge controller, and a 5000-watt modified sine-wave inverter, converting 12 volt DC electric power from the solar module, and batteries to 120 volt AC for typical household electrical tools and appliances.

These training courses and workshops are normally open to foreign participants. Government officials or concerned organizations in other APEC member economies may consider sending their staff to attend such courses. Another option is to organize such training programs in their economies with their local experts or to invite foreign experts to conduct training courses.

6.2 Recommendations to Increase the Utilization of Village Power Technologies in Community Reconstruction

Village power technologies can be economical, functional, and sustainable. They can be ideal in the reconstruction of communities after disasters, when building a new community, or when expanding the existing community due to normal economic growth. For all new development in areas prone to disasters, disaster resistant designs should be adopted in addition to the installation of resilient village power systems.

The lessons learned from past and current village power programs in different economies show that very similar issues resulted in unsuccessful village power programs. Those issues are related to (1) knowledge of the technology, (2) training and education of users and local technicians, (3) system maintenance and routine check-ups, (4) system ownership and revenue collection, (5) government policies and regulatory framework

[78] www.ncsc.ncsu.edu/

[79] www.longbrancheec.org/

supporting renewable energy based village power technologies, (6) commercialization of technologies, (7) financial mechanisms, and (8) initial costs of technologies.

The United States' National Renewable Energy Laboratory (NREL) has been working to match renewable energy technologies with rural energy needs in the international market through their “Renewables for Sustainable Village Power (RSVP)” program since 1994.[80] NREL has worked with in-country authorities on various renewable energy pilot projects around the world. One of the most important contributions from the RSVP program is to share lessons learned in developing these pilot projects. Lessons learned from the NREL’s RSVP program[81] and from the current and past village power programs discussed in Chapter 4 are used to create recommendations to promote greater use of village power technologies in APEC economies.

Technology Knowledge

The project implementers need to understand the technology being adopted thoroughly before implementing it. They also need to understand local resources. Resource assessments should be conducted to understand resource options and to help determine a cost-effective technology. The village power solutions for rural electrification should be based on resource availability and on the villagers’ electrical demand as well as their willingness and ability to pay for the service, not on a pre-selected, specific technology or application.

The deployed systems need to be well tested prior to installation in remote locations. Systems should be robust, reliable, and simple to operate.

Networking and information sharing should be a common practice in the economy so technology knowledge can be transferred and successful projects can be replicated.

Pilot Projects

Implementing pilot projects is an important first step in the development of a commercially viable market for renewable rural solutions. Pilot projects are central to renewable energy-based village power development, as successful pilot projects will enable new technologies to be replicated. If pilot projects fail, it will be difficult to initiate a village power project of the same type elsewhere. Pilot projects need to have sustained support and replicability. They need commitments of time and financial resources. Pilot projects should be implemented over multiple years and with sufficient funds for operation.

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[80] www.rsvp.nrel.gov/

[81] R.W. Taylor, “Lessons Learned from the NREL Village Power Program,” Presented at the 2nd World Conference and Exhibition on Photovoltaic Solar Energy Conversion; 6-10 July 1998, Vienna, Australia; and L. Flowers, et. al. “Renewables for Sustainable Village Power,” Presented at the American Wind Energy Association’s WindPower 2000 Conference; April 30- May 4, 2000, Palm Springs, California, USA.

Pilot projects need to be designed with a path toward commercial replication both technically and conceptually. Pilot projects that do not have a path to commercialization and serve only as demonstration projects will have less value to the existing electrification program and will not significantly expand the adoption of these technologies in the economy.

Based on NREL's experience, single projects in remote locations are not sustainable. Multiple systems in a region are needed to develop and sustain the necessary support infrastructure.

Project Designs

A strong local partner is essential to the success of the project. The local partner will develop hands-on experience and use it to replicate future projects. This partner will be the voice of the project and the one who can sustain the momentum during project implementation. The local partner will also understand the local legal, political and social context and therefore can help shape the project to fit local communities. Pilot projects normally take two to three years from site selection to project completion. Thus, the long-term cooperation and commitment of the local partner must be realized.

A project maintenance support infrastructure needs to be established in the economy. An existing local organization should be selected to work as the project's supporting organization. This supporting organization will be responsible for training, trouble-shooting, problem solving, spare parts inventory, system repairs, etc. The newly installed village power systems will be neglected without good maintenance support.

A well-designed administrative system needs to be in place to manage new village power systems. Transparent procedures for financing, fee collection, and disconnection services (if fee is not paid) have to be set, and strictly enforced.

The project should be designed to promote a partnership between public and private sectors. The government should implement the project with private sector involvement and a path toward commercialization.

Project Implementation

The project needs sufficient budget to carry the work through to completion without compromising system size or quality. In many solar home system projects, for example, small project budgets resulted in the installation of solar home systems that were too small and that relied on low quality system components. When the systems were too small, homeowners were dissatisfied and intentionally overloaded the system, causing system breakdown. The low quality of system components caused frequent system failures.

Using system components imported from foreign companies with no local representatives can lead to maintenance problems when the systems require repair.

Public misperception and acceptance of a technology can pose problems to a newly implemented renewable energy project. Public campaigns and education provide people with a better understanding about the project and contribute to the project's success.

Project Operation

Effective communication and a modern information management system are needed so that the problems at the sites (i.e., equipment problems, late payment, etc.) can reach proper management in a timely manner.

Professional technicians are needed for routine checks and system maintenance. In communities without any defined arrangements specifying who was in charge of system maintenance, the systems in need of repair were put out of use, if not permanently, then for long periods of time

Stocking adequate spare parts for system maintenance and replacement is essential to avoid long waits for repair. Failure to address maintenance issues and to provide maintenance funding has resulted in failures of many past solar home system projects.

Fees for maintenance and replacement of parts should be collected regularly. In addition, fee collection should be standardized among users to avoid resentment of customers.

Financing Arrangements

Village power technologies normally have high initial costs. This can present a great barrier for villagers wishing to obtain these technologies if they have to purchase and own the technologies, especially when villagers lack lines of credit. Appropriate pricing and cost recovery strategies are important to ensuring sustainable services from the project. System and service pricing must not be so high that villagers cannot afford to pay, nor so low that costs cannot be recovered thus requiring permanent government subsidies.

To make village power technologies such as solar home systems more affordable to villagers, these systems may be provided to villagers at lower than actual capital costs with a subsidy from the government or a donor. The systems, however, should not be given away for free. It will create a sense of ownership if villagers have to pay for their own systems. The government might subsidize the program by buying down the high initial cost of solar home systems. However, subsidization should not be made to finance operating costs and should not be made indefinitely. The project must be designed to have users pay for the services they receive and to be financially self-sustaining.

Financial arrangements should be designed to reflect users' willingness and ability to pay, and should aim for full cost delivery. Arrangements with high down payments for the system and short pay-off periods limit the purchase to higher income groups. Low initial payment and longer pay-off periods would attract more buyers, but could increase defaults in the project. Financial structures should be low enough to attract customers but high enough to cover all costs and avert possible defaults. Rural households with irregular income streams may require seasonal rather than monthly payment schedules. Proper financial arrangements should be tailored to fit each community's needs and energy planners should design financial arrangements that are reasonable and reflect the users' ability to pay.[82]

Capacity Building

Local capacity building is an important aspect of village power projects. Strengthening local capacity will increase the chance of projects' success and increase the likelihood of technologies being maintained and replicated elsewhere in the economy. Capacity building can be accomplished by formal training such as workshops or seminars as well as through hands-on experience in pilot projects.

Local technicians need to be trained to fix and maintain the installed village power systems so timely services can be provided to customers when needed. Regularly scheduled refresher courses also need to be provided to existing technicians so they can keep their skills up-to-date. It is also important that multiple technicians be available since in rural areas it is common for a trained technician to leave the area for a higher paid job in a city. Local training (including having operating manuals in the local language) as well as regional operating and maintenance capability is critical for sustainable operations.

Users should also be educated so they will have the correct perception about the system they are acquiring and understand how to use it properly. For example, users have to understand the capabilities of their solar home system. Unrealistic perceptions (such as belief that a small 100-watt peak system can power large household appliances) will lead to dissatisfaction and improper utilization of the system. It has been shown in several cases that solar home systems failed because of users' improper application of the systems.

Economic Analysis

Life cycle cost analysis should be adopted when evaluating cost effectiveness of a renewable energy system. Village power technologies often involve high upfront costs, but they have low operating and no fuel costs. All costs that system will incur during its expected lifespan have to be taken into account for a fair cost comparison when deciding between a conventional power system and a renewable energy village power system. In areas prone to disasters, it could prove more cost effective to invest in self-sufficient village power technologies that could prevent large business losses caused by power outages during and after disasters.

[82] http://www.worldbank.org/astae/pvpdf/chapter6.pdf

Institutional Support

To make village power technologies a mainstream rural electrification option or a concrete contribution to poverty alleviation, they must be integrated into the economy's national development plan. The coordination of village power technologies into other rural development programs, i.e., education, health, economic development, agriculture, etc., will increase the success of utilizing more village power technologies in the economy.

Policies that help promote greater use of village power technologies need to be in place. In many economies, tax credits, rebates or low interest loans for renewable energy systems have proven to be effective tools for encouraging consumers to adopt renewable energy systems. A policy such as net metering that allows extra electricity to be sold back to the grid provides an incentive for consumers to obtain their own wind or solar systems and connect to the grid. This can help shave peak loads for the utility and save investment costs in expanding conventional power generating capacities.

Governments should implement policies that help reduce market distortion. One example is to rationalize import duties and taxes of village power technologies so they can compete in the market with other power supplies. High import taxes and duties on PV modules or system components, for example, will increase the cost of solar home systems and make them less affordable and prevent large scale development of a commercially viable, market-based solar home system program in the economy. On the other hand, the policies to subsidize other rural energy options such as subsidizing kerosene prices or prices of grid electricity will lower the costs of these energy options below their real economic values. Although the policies such as these can be defended on social grounds, they will make village power technologies more expensive and less desirable.

Governments should create policies to support large-scale markets for village power technologies. Production costs of village power technologies depend significantly on volume. For example, significant cost savings can be obtained by purchasing PV products in bulk. Large-scale markets will also lower maintenance costs and other support services, which will increase user satisfaction with the technology.

Standards for village power technologies, their system products, and components should be established (either at national or international levels) to guarantee product quality and system reliability. This will increase user confidence in these "new" technologies. The standards should also include ratings and verification tools for appropriate sized systems. The standards should be consistent and strictly enforced.

Governments should establish financial procedures to facilitate access to credit lines, loan guarantees, low interest rate loans, or other financial mechanisms that will increase users' ability to afford village power technologies.

Finally, governments need to lay out a transparent, supportive institutional and regulatory framework to encourage renewable energy technology market development and expansion. Governments should also provide strict oversight of manufacturers and service providers to ensure that product standards are met and product warranties are honored.

Chapter 7

Conclusions

Natural disasters happen at different levels of severity. The 2004 Indian Ocean tsunami was a catastrophe that killed several hundred thousand people and damaged hundreds of villages along the coastal line of the Indian Ocean. After the 2004 tsunami, there were several more disasters that hit both APEC member economies and countries around the world. The Nias Earthquake off the west coast of northern Sumatra, Indonesia in March 2005 killed approximately 1,300 people on the island of Nias and left tens of thousands homeless.[83] A powerful earthquake devastated the Pakistan-India border region in October 2005 and killed at least 83,000 with millions more left homeless.[84] Hurricane Katrina, one of the deadliest hurricanes in the U.S. history, struck the U.S. Gulf Coast in August 2005, killing at least 1,800 people.[85] An earthquake struck Indonesia in May 2006 and impacted eight districts within Yogyakarta province and the neighboring Central Java province, severely damaging housing and infrastructure, and killing between 5,000 and 6,000 people with 20,000 injured and over 200,000 displaced.[86] This is to name but a few. Inevitably, disasters will happen again in the future. While we cannot stop future natural disasters, we can prepare and respond better to such incidents.

This project was designed by EGNRET in order to foster a better understanding of the role of village power technologies in the tsunami recovery efforts in the three APEC member economies affected by the 2004 tsunami—Indonesia, Thailand, and Malaysia, to identify the obstacles which might have been present that prevented the increased use of village power applications, and to document lessons learned in order to serve as a basis for developing guidelines for the future rapid utilization of village power systems in the aftermath of future natural disasters in the APEC region.

Many village power technologies are commercially available and have proven to be useful for disaster response. These village power technologies were, however, not adopted in Thailand and Malaysia, and were used on a limited scale in Indonesia (e.g., seven units of PV powered emergency telephones). It was also interesting to learn that the organization that utilized this technology was not the one with direct responsibility for disaster response. The obstacles that prevented use of village power technologies in the tsunami disaster response identified by the government officials and organizations responsible for tsunami relief in Indonesia, Thailand, and Malaysia included: (1) high initial costs of technology, (2) no funds available for the purchase of village power technologies, (3) lack of knowledge about technologies, (4) lack of knowledge about suppliers, and (5) lack of expertise to implement and maintain the technologies.

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[83] http://en.wikipedia.org/wiki/2005_Sumatran_earthquake

[84] http://www.npr.org/templates/story/story.php?storyId=4954200

[85] http://en.wikipedia.org/wiki/Hurricane_Katrina

[86] http://ochaonline.un.org/cap2005/webpage.asp?Page=1375

Village power technologies such as off-grid solar electric systems, solar hybrid with wind and/or diesel electric systems, and micro-hydropower could have been used for reconstruction in the tsunami-impacted communities. These technologies have since been adopted to some degree. These include the projects completed in Indonesia for sixty off-grid solar electric systems, a micro-hydropower plant, a solar/wind power hybrid system, and solar-powered tsunami early warning systems, and possibly future projects using more micro-hydropower and wind power. In Thailand and Malaysia, since most impacted areas were electrified, village power technologies for electric systems were not adopted for community reconstruction, but the damaged parts of power systems were repaired. In Thailand, one solar home system was installed for an unelectrified home on a tsunami-impacted island, one solar power electric system was installed in an unelectrified rural school, and solar-powered tsunami warning systems were utilized. As was the case with emergency response, the organizations that used these technologies for reconstruction activities were normally not the government agencies with direct responsibility for community reconstruction.

The lessons learned from past and present village power programs identified several issues that resulted in unsuccessful village power programs, including: (1) knowledge of the technology, (2) training and education to users and local technicians, (3) system maintenance and routine check-ups, (4) system ownerships and revenue collection, (5) government policies and regulatory framework supporting renewable energy based village power technologies, (6) commercialization of technologies, (7) financial mechanisms, and (8) initial costs of technologies. These issues were identified from various village power programs in different economies. Surprisingly, the issues and problems were consistently similar, as if little was learned from past experience.

This report recommends various types of village power technologies that could provide useful services to an economy in disaster response. The report also recommends the village power technologies that governments should consider utilizing when reconstructing communities after disasters as well as in new community reconstruction. These technologies will provide clean energy to communities under normal circumstances and will assure that they will have power during disasters when grid power is not available. They will make communities less dependent on imported fuels and increase disaster resilience. In any circumstance, energy efficiency should be a primary focus when reconstructing communities. If less energy is needed, communities will be less dependent on energy and more resilient when electricity is not available during disasters and when portable generating systems are required.

Several recommendations are proposed in this report based on the identified obstacles and issues that might prevent greater use of village power technologies. The recommendations to promote greater utilization of village power technologies for disaster response include: (1) advanced planning and coordination, (2) identifying and understanding appropriate technologies, (3) pre-identifying potential suppliers, and (4) early training on technology utilization. The recommendations to increase the use of village power technologies for community reconstruction or on new community development involved the issues of: (1) technology knowledge, (2) pilot projects, (3) project designs, (4) project implementation,

(5) project operation, (6) financing arrangements, (7) local capacity building, (8) life-cycle cost analysis, and (9) institutional support.

This project also recommends that in order to guarantee product quality and system reliability, the establishment of standards for village power technologies, their system products, and components is needed.

The past APEC projects under APEC 21st Century Renewable Energy Development Initiative Collaborative IV: Renewable Energy Standards have been enormously successful in establishing the foundation and the related infrastructure for the harmonization of renewable energy standards. The completed Chinese-led project in 2002, *"Adoption of Renewable Energy Standards in the APEC Region,"* worked with member economies to identify the national and international standards for renewable energy in a resource guide format. The project identified where there is a need for standards but where none currently exist, and developed a draft action plan of key milestones to implement those standards. The project *"Adoption of Renewable Energy Standards Phase II Final Groundwork,"* led by the U.S. in 2005, identified three priority areas for harmonization of standards: manufacture and installation of solar water heaters, installation of PV grid-connected systems, and installation of standalone power systems.

There is a growing interest in standards for renewable energy and energy efficiency technologies and training in the region. For instance, the Chinese government is supporting development and adoption of standards, especially for rural electrification applications. Similarly, the Malaysian Energy Center is developing standards for energy efficiency and new energy technologies. The project *"Development and Implementation of a System for Accrediting Renewable Energy Training,"* self-funded by Australia and undertaken under the APEC 21st Century Renewable Energy Development Initiative Collaborative III: Renewable Energy Training and Certification Network developed and recommended a system for accrediting renewable energy training within the APEC region. Clearly, there is momentum for harmonized renewable energy standards and a great need for coordinated activities in the region. Having harmonized standards for village power technologies, especially for disaster response, will increase user confidence in these "new" technologies, and help promote greater use of the technologies.

<u>Proposed Next Steps</u>

It is clear from an examination of the lessons learned from the 2004 Asian tsunami that village power technologies could have played an important role in the initial disaster response. Although these important village power technologies were available, they were not utilized due to a number of structural problems that were identified in this report. Thus, a potential next step would be to develop an APEC project to work towards the implementation of the project recommendations associated with disaster response as mentioned in the report. One specific project would be for APEC to work with the private sector to set up standards and certifications of renewable energy products especially for disaster response. Another potential project would be for APEC to organize training courses and workshops covering topics related to the impacts of different disaster types and the most appropriate emergency response management, planning, and operations that include village power technology applications, operations, and maintenance.

Finally, since disasters have been occurring on a regular basis, APEC could establish a continuing project to identify where village power technologies have been utilized, to evaluate their effectiveness for disaster relief purposes, and report the information on a web site so that important lessons learned and successfully deployed technologies can be shared with others.