



## Renewable **Energy Options** on Islands in the **Andaman Sea**

A feasibility study for  
hybrid renewable energy/diesel systems  
in two Tsunami impacted  
communities

By the communities of Koh Pu and Koh Po,  
King Mongkut University  
of Technology Thonburi,  
International Institute for  
Energy Conservation  
and Palang Thai

**Tsunami Aid Watch** is a project of the Southeast Asia Regional Office of Heinrich Böll Foundation, in co-operation with Southeast Asia Consult and Resource Co., Ltd.

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**In cooperation with:** the communities of Bahn Koh Pu and Bahn Koh Po  
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## **Krabi Declaration on Sustainable Post-tsunami Rehabilitation**

The participants of the forum would like to extend their gratitude and heartfelt thanks to all individuals, communities, national and international groups, parties and organizations for the help and aid they have provided for the individuals and communities affected by the tsunami of December 26th 2004. We hope that they will continue to give us unwavering support during the remaining task of long-term rehabilitation. The tsunami has left Indonesia, Sri Lanka, India, Thailand, the Maldives and other countries with devastated coasts, shattered communities, economies and hundreds of thousands of people in need of support. This destruction was, however, only the initial direct impact of the tsunami disaster. The ensuing aid efforts were part of just the first phase of tsunami rehabilitation.

Nine months have now passed since the tsunami and in most affected areas treatment has been delivered to the wounded and basic shelter is available for the surviving victims; in many cases the boats and fishing gear needed for livelihood restoration of the fisher folk have been provided; the remaining tasks are ready to be overseen by restored community structures and local administrations. The situation can, thus, in most instances be described as approaching stability. However, it is a far cry from being normal.

The tsunami recovery now enters a second phase of transformation that is the recovery from a disaster into a more permanent and functioning economic and social set-up, i.e. the mitigation of the secondary tsunami impact. While the aid to rehabilitate from the initial direct impact of the tsunami was characterized by speed and efficiency, the recovery support effort needed for the indirect impact recovery must strive for long-term effectiveness and sustainability. Taking into account livelihood, economic recovery, disaster management, issues of land and housing for the displaced, the landless, women, children, gender issues as well as migrant labor problems. In order to achieve this, a number of measures are urgently needed. Based on past aid delivery experience we therefore ask the international community and supporting NGOs and GOs to mobilize all available resources to:

- Ensure that the long-term rehabilitation of the tsunami affected area is based on definitions of fairness, justice, sustainability and stability as perceived and defined by the tsunami affected communities and individuals;
- Develop the secondary tsunami recovery support into an opportunity to address and solve pre-tsunami problems that have been worsened and/or exposed by the disaster;
- Deliver assistance and support in an accountable and transparent form that ensures participation of those affected in planning, implementation and execution of long-term rehabilitation programs;

- Establish – a vitally important point – a proper, honest and forward-looking information system and data-base on the tsunami disaster for the use and to the benefit of its affected individuals and communities, independent of nationality, race or religion;
- Initiate an aid-tracking system / mechanism to avoid the misuse of aid-resources or its appropriation for something other than aid purposes;
- Ensure that the remaining rehabilitation becomes a stepping stone for further development of the affected areas leading to better conditions than before the tsunami disaster.

If the international community, governments and civil societies help to continue with the tsunami recovery support based on the conditions given above, the tsunami disaster itself can be turned into an opportunity for development that is in line with sustainability needs and economic progress of all mankind. We believe in the in the strength of cooperation, coordination, openness and solidarity in times of need.

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## Acronyms (Database of Abbreviations)

Abbreviation	Full Name/Expression
AC	Alternating Current
Ah	Amp hour
BOD	Biochemical Oxygen Demand
BTU	British Thermal Unit
CBOs	Community Based Organizations
DC	Direct Current
DEDE	Department of Alternative Energy Development and Efficacy
E & Co	Energy through Enterprise
ENCON Fund	The Energy Conservation Fund
EPPO	Energy Policy and Planning Office
ESCO	Energy Service Company
GEF	Global Environment Facility
GO	Government Organization
hr	Hour
Hz	Hertz
ITPI	IT Power India
IVECO	IVECO Generator
JGSEE	The Joint Graduate School of Energy and Environment
KMUTT	King Mongkut University of Technology Thonburi
kVA	Kilo Volt Amp
kW	Kilo Watt
kWh	Kilo Watt Hour
kWp	Kilo Watt Peak
LPG	Liquid Petroleum Gas
NGO	Non Government Organization
O&M	Operation and Maintenance
PDTI	Pilot Plant Development and Training Institute
PEA	Provincial Electricity Authority
PV	Photovoltaic
REEEP	Renewable Energy and Energy Efficiency Partnership
SEPS	Sustainable Energy Project Support
SHS	Solar Home Systems
SMA	SMA Technologie AG
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VCD	Video Compact Disc
W	Watt

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## Preface

The Tsunami Aid Watch Programme (TAW) was initiated by the Heinrich Böll Foundation's (HBF) Southeast Asia Office in July 2005 to systematically monitor impact of Tsunami aid packages and the mechanisms of implementation. It is a specific contribution to the larger Development Watch initiatives that the Southeast Asia Programme of HBF has implemented for many years applying sustainable development criteria in its advocacy, enhancing participatory democracy and civil society engagement as well as good governance principles in Thailand's development process.

TAW aims at systemic analysis of development and aid structure deficiencies, mechanisms and processes on the basis of concrete case studies examined in the context of Tsunami recovery and rehabilitation activities. TAW will link these results to general structural characteristics of Tsunami recovery assistance in the region. TAW will help to define a political perspective towards process and structures of aid delivery for Thailand.

As part of the best practice aspect of the Programme, an approach to developing sustainable concepts in mid- and long-term recovery including social, economic and ecological aspects is part of TAW. This publication of **Renewable Energy Options on Islands in the Andaman Sea** is the second publication of TAW to focus on such conceptual issues. It is a fully fledged project preparation study on how to make the most effective and efficient use of existing energy generation capacities in order to provide two villages located on the islands of Koh Pu and Koh Po with a 24 hour energy supply, whilst at the same time optimizing the potential of renewable energies under the current economic and political conditions.

The development of this hybrid energy system concept links to the extended 'Energy and Climate Change' programme that HBF conducts in Thailand. HBF's activities within the framework of this programme are directed at promoting renewable energies at the national policy level, against the backdrop of looming climate change and transforming energy policies in the global political economy. In order to succeed on the macro level, promising projects at the community level are of utmost importance to illustrate the feasibility and future economic, social and environmental prospects of sustainable, environmentally friendly technologies. (cont.)

The foundation wishes to thank the authors of this study and all members of the participating communities. The concept presented in this publication is a direct result of their effort to build economic, social and ecological bridges between community development and environmental needs. These two perspectives are sometimes perceived as contradicting one another but do not necessarily do so. The example presented in this study shows that in the mid-term Tsunami recovery process they can merge to contribute to an environmentally, economically and socially sustainable path of development.

February 2007

**Dr. Heike Löschmann**

Director

Southeast Asia Regional Office, Heinrich Böll Foundation

## Preface

The post Tsunami recovery and reconstruction process has been an enormous challenge for impacted local communities, while at the same time offering an opportunity to rebuild, develop and improve social, economic, political and administrative structures. This aspect of 'an opportunity in crisis' has already been introduced, discussed and publicly addressed by the International Krabi-Conference on Tsunami Rehabilitation in September of 2005 (see the Krabi Declaration before the table of contents).

As a conference participant and co-author of the Krabi declaration, the foundation's mid-term recovery project 'Tsunami Aid Watch Programme' (TAW) focuses on developing this issue as one of the five main themes of activity. This concept of **Renewable Energy Options on Islands in the Andaman Sea** in a hybrid system is one of the results and has been achieved in a process lasting nine months.

The technical study with a supplement on the successful management and operation of a hybrid energy system on the Andaman island of Koh Jig was coordinated by Prof. Dr Christoph Menke JGSEE/KMUTT (King Mongkut University of Technology, Thonburi) and conducted by Sirikul Prasitpianchai (International Institute for Energy Conservation, IIEC, Asia Regional Office, Bangkok), Tawatchai Suwannakum (PDTI, King Mongkut University of Technology, Thonburi) and Chris Greacen (Palang Thai, Bangkok). As part of the process TAW initiated discussions with the two participating communities on the islands of Koh Pu and Koh Po, since their support and active participation is crucial for the success of the project.

In the aftermath of the Tsunami the two villages found themselves being equipped with home solar systems provided by the government of Thailand and diesel generators donated by UNICEF to support recovery efforts. As the following shows, despite the donated electricity generating capacity the villagers could only benefit from an electricity supply for a few hours each day and besides this, important parts of the equipment failed. However, the conclusions of this study suggest that by using the existing workable components as a base, the creation of a hybrid energy system using diesel and renewable energy sources could provide a sustainable 24 hour-electricity supply for the villages.

With this concept we are able to combine securing future development opportunities for the villages concerned and a sustainable mode of energy generation that contributes to paving the way to a new solar era, which should be grasped with both hands, faced as we are with the looming change in our climate, fueled by socially and environmentally detrimental mega energy generation projects. (cont.)

More than two years after the Tsunami, the immediate recovery period is about to end and the mid-term recovery stage is in operation. Now that a very high degree of normalcy created by communal emergency-synergies has been achieved, it is fundamental to link the Tsunami recovery and rehabilitation efforts to an overall sustainable development process in Thailand.

In the case presented here, a concept to enhance environmental, social and economic sustainability can draw upon a strong network of NGOs and academic institutions to ensure its success. What is lacking now is the continued financial support and commitment by donors (beyond the availability of news images depicting immediate relief delivered to victims).

We, the Save Andaman Network communities of Bahn Koh Pu and Bahn Koh Po, and the Tsunami Aid Watch team sincerely hope that our reading audience will appreciate the development opportunity we have presented in this study and help the communities with the initial funding for the project.

February 2007

**Karl H. Segschneider**

Director of the Tsunami Aid Watch Programme of Heinrich Böll Foundation

# 1. Introduction

Remote islands in Thailand have an expensive, intermittent, and limited electricity supply from failure-prone solar home systems and costly diesel generators. The lack of convenient, affordable and reliable electricity hampers Tsunami recovery efforts, and limits the ability of locals to develop their communities in ways that they would like to. Currently household appliances are limited to lighting, radios, small televisions, and VCD players. Power tools such as the drills and saws necessary for boat/house repair and construction are only currently possible through the use of expensive, noisy, and maintenance-intensive diesel generators. Refrigeration – for food and vaccines – is beyond the reach of these communities because solar electric systems are too small to power refrigerators and high diesel prices mean that the generators are only run for several hours each evening.

Fortunately, much of the equipment necessary for 24-hour, reliable electrical system is already in place. In most remote communities in the country, including those on Tsunami-affected islands, the Thai government has provided each household with a solar home system. Though many of these systems are failing (mostly because of poor quality inverters and fluorescent ballasts), the solar panels themselves are a significant and robust asset which, collectively, could contribute a significant amount of power to an integrated electricity system. Similarly, UNICEF has provided diesel generators to many island communities affected by the Tsunami. These generators alone, however, are an expensive source of power, as diesel fuel is expensive on remote islands. In addition, lack of local knowledge on how to effectively use and maintain the generators limits their effectiveness, efficiency, and long term sustainability. Finally, while some communities have good democratic local governance institutions to manage local resources, these are not yet adapted to the sustainable management of electricity systems at the community scale – which are a new technology with particular characteristics.

This project addresses the high costs, poor reliability, and current poor performance track record of current electricity sources by working with villagers in two islands to develop plans for a state-of-the-art village-scale hybrid diesel-renewable energy system, and accompanying local expertise to sustainably manage these systems (both financially and technically). Based on experiences in a similar island community with a hybrid renewable energy system (Koh Jig) in Thailand, electricity costs to village users are expected to decrease, while electricity availability and power quality is expected to substantially increase.

The study is broken into two sub-studies, one for the island of Koh Pu and one for Koh Po. Each sub-study begins with a discussion of electricity demand on the islands (both current demand and expected demand growth). This is followed by description of the current arrangements for provision of electricity, and accompanying problems. Next is a description of an optimized hybrid system that would make use of existing resources (solar panels, diesel generators, wind sites) and new equipment to improve the electricity service and lower costs to end-users. Next the financial costs of the hybrid system are considered, with a sensitivity analysis that considers the impact of changes in diesel price, the future load on costs and optimal system configuration. Finally there is a step-by-step implementation plan and suggestions of debt, equity and grant funding options. As an addition, the lessons learned from an existing solar/wind/diesel project on the island Koh Jig are considered, and a technical Attachment discusses synchronization issues that arise from operation of multiple diesel generators on the same electrical system.

## 2 Koh Pu

### 2.1 Demographic Profile

Koh Pu is a small island approximately 10 kilometers (north to south) by 4.5 kilometers (east to west). The island is located about 3 kilometers west of the mainland Krabi province in the Southern part of Thailand (latitude of 7°50'N, longitude of 98°57'E). Koh Pu is among other small islands governed under the sub-district of Koh Sriboya. It has three villages officially numbered as villages 2, 3 and 5, with approximately 500 houses in total. Only village 2 is chosen for this preliminary renewable energy options study because the village was deemed by the Save Andaman Network (SAN) to be most organized and most able to effectively operate the project in the long term.



**Figure 1:** Google Earth satellite photo of Koh Pu. The marker indicates the location of village #2. (7 deg 51 min North, 98 deg 57 min East)

Village 2 or “Bahn Koh Pu” has approximately 150 houses with a population of 1,160. The age structure is as follows:

Age profile	Quantity
0-14 years	385
15-20 years	155
20-60 years	520
> 60 years	100

**Table 1:** Population demographic of Bahn Koh Pu

The majority of the families' primary income derives from small scale near-shore fisheries using boats of five meters or less. Most are family-owned and operated. As fish catch depends on weather and tides, fishermen can only cast their nets for 15 days at most in one month. In the peak season, a family can earn up to 20,000 Baht per month. During the monsoon season (May-October), fishermen make less frequent fishing trips and rely more on shell collection onshore. During these times incomes can be as low as 3,000 Baht per month. Some houses have small shops selling groceries and fishing equipment to the local community. A small number of families own land on the island with rubber plantations. Rubber tree growers tend to be wealthier than the fishermen. Selling unprocessed rubber sheets at 80-100 Baht/kilograms can earn up to 600,000 baht/month for the families. A rough estimation for occupations on the island is 85% fisheries, 10% shops, and 5% rubber orchards.

Koh Pu is not yet a tourist destination; however there are a couple of small bungalows on the east side of the island in Village 3. Locals report that beach-front property prices have increased four-fold in the past few years from speculation by outside investors planning to open up new tourist destinations. This could potentially contribute to future changes in the local economy, culture and social structure on the island.

The foremost hindrance to tourism development on Koh Pu is the lack of electricity. It is unlikely that a grid extension could be possible in the near future as the current electricity demand on Koh Pu is low and not economically viable for Thailand's public utility, the Provincial Electricity Authority (PEA), to invest in the expensive underwater cable to connect Koh Pu with the mainland's grid system. The planned hybrid system discussed in this paper presents the possibility of expanding electricity supplies in ways that are controlled by the community itself, which can serve as a tool for the community to control unwanted forms of tourism development.

## **2.2 Energy demand and supply assessment**

### **Current energy demand**

The power supply for Bahn Koh Pu comes from three sources: two diesel generators (each 30 kVA), 128 Solar Home Systems (SHS) (120W) and a dozen or so small diesel generators. Generator #1 is located near the mosque and serves only 40 houses and the mosque itself. Generator electricity is used an average of four hours per night (6.30 PM – 10.30 PM) and the solar systems are mostly used for the daytime load. Villagers pay electric bills that vary from 300 to 1,000 Baht per month per household. The tariff is 25 Baht per kWh, and villagers reported that this amount is sufficient to cover the cost of diesel fuel but not depreciation of the generator. Currently, there is no charge for using the SHSs. The rest of the houses that are not connected to the

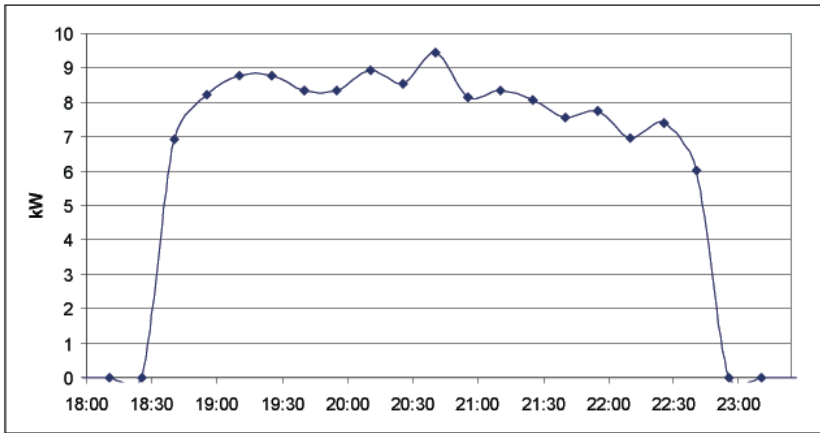
30 kVA-generator use a SHS and their own small generators. The second 30 kVA-generator (generator #2) is used primarily to power woodworking tools (drills, planers, saws, grinders) in a boat yard that builds and repairs fishing vessels, but is also connected to several houses nearby.

A survey of 20 houses (out of 40) connected to the village's diesel generator #1 shows that typical appliances used are two to five fluorescent lamps, a 20" color TV, a VCD player and a fan. A few houses have stereos and only two houses have washing machines. The rest of the houses that are not connected to the community generator have similar appliances. An estimation of energy demand for all 150 houses using the same pattern of usage with the same array of appliances is 160 kWh per day with the peak demand at 40 kW.

Appliances	Power (Watts)	Number of appliances	Hour of use	Energy demand (kWh)
Fluorescent lamp	18	300	4	21.60
Fluorescent lamp	36	300	4	43.20
TV 20" color	75	150	4	45.00
Stereo	30	100	4	12.00
VCD player	25	150	4	15.00
Fan	35	150	4	21.00
Washing machine	270	2	4	2.16
Mosque's sound broadcast	90	1	4	0.36
<b>Total</b>				<b>159.96</b>

**Table 2:** Current energy demand in village Bahn Koh Pu (May 2006).

In addition to surveys, the team used a datalogger to record electricity supplied by Koh Pu's generator #1 on the night that the team stayed on the island. The data shows the 30 kVA generator turning on at about 6:30pm, with fairly constant demand between 8 and 10 kW tapering slightly in the later hours to 7-8 kW until the generator is shut off at about 10:40pm. The generator was not turned on in the morning.



**Figure 2:** Koh Pu electricity demand from generator #1 on 29 May, 2006. Integrating the graph above reveals that cumulative daily demand is currently 34 kWh/day for about 40 households connected to the generator. Extrapolating to 150 households suggests an amount nearly equal to the 160 kWh cited in Table 2

### **Current organizational structure for electricity provision**

The two diesel generators were donated by the UNICEF a few months after the tsunami destroyed the fishermen’s houses and boats. The original intention of the generators was to power tools for the reconstruction. Although, there is no official notation for the ownership of the generators, the perception of villagers is that they belong to the community. The provision of village electricity is loosely organizing by the village headman and some affiliates to the mosque. The electricity price is adjusted by these leaders and the community at Friday’s prayers on an occasional basis to adjust any significant changes in diesel price. The electric bills are collected every 15 days by the mosque committee. Although the electricity is charged at 25 Baht per kWh from meter readings, the meters are not accurate enough for measuring amounts of energy less than one kWh and some of the houses with few appliances and just a couple of lights end up paying excess charges. The committee has decided to charge 100 Baht per light, which is a simple but not particularly equitable solution. Some of these houses have decided to disconnect from the network and return to using batteries. The current organizational structure has not yet posed any serious disputes among the community. However, there is scope for improvement to ensure that everyone has access to electricity at an affordable and fair tariff.

The operation and maintenance of the generators are the responsibility of the mosque committee and the boat craftsmen. The islanders are fairly familiar with similar diesel engines and small diesel generators for their houses and boats.

### Scenarios for future energy demand

The current electricity supply limits the use of appliances. From the survey, most of the villagers expressed their wish of having refrigerators and rice cookers if they could have access to a 24-hour service of grid quality electricity. To estimate future demand for electricity in Koh Pu, two techniques were used. First was a “bottom-up” approach in which villagers were asked what appliances they would use if a 24-hour electricity service were available. Survey results are shown below in Table and suggest a future demand of 419 kWh per day.

Appliances	Power (Watts)	Number of appliances	Total Power (kW)	Hours per day	Days per month	Total kWh
36W Fluorescent light	36	452	16.20	4	30	1,944
11W Fluorescent light	11	226	2.48	8	30	594
20" color TV	75	162	12.15	6	30	2,187
15 cu.ft. Refrigerator	200	45	9.00	6	30	1,620
6 cu.ft. Refrigerator	90	105	9.45	6	30	1,701
Fan	35	263	9.19	6	30	1,654
Iron	1,000	32	31.50	1	10	315
Rice cooker	530	132	69.96	1	25	1,749
Microwave	1,200	8	9.00	0.25	30	68
Washing machine	305	32	9.61	2	10	192
Stereo	65	53	3.41	4	30	410
Electric water boiler	650	8	4.88	1	25	122
Mosque loudspeaker	90	1	0.09	4	30	11
<b>Total kWh/month</b>						<b>12,566</b>
<b>Total kWh/day</b>						<b>419</b>

**Table 3:** Koh Pu load forecast model using household appliances. Number of appliances used is a statistic of an average number of appliances in typical Thai households from a sub-study used in developing Thai electricity demand forecast.

The second technique was based on actual electricity demand profiles from a similar island (Koh Jig) with a hybrid system (installed in 2004), adjusted by population differences between the two communities. In Koh Jig actual daily energy demand has been recorded using a datalogger in 15 minute intervals over a year of operation. During the first three months of hybrid system operation, villagers bought many refrigerators and other appliances. The energy demand escalated from its before-hybrid-system-level to the current level, and has since more or less stabilized. We assume that Koh Pu’s demand profile will behave similarly to Koh Jig, with much of the energy demand increase attributable to the high power consumption of appliances such as refrigerators. Koh Jig’s daily energy demand is currently 275 kWh with the peak demand 28 kW at around 8:00 PM as shown in Figure 3. The electricity demand profile on Koh Pu is estimated using Koh Jig’s demand profile, adjusted by a coefficient equal to the population ratio of the two villages. On

this basis, Koh Pu's future electricity demand is estimated to be 412 kWh per day with a peak demand of 42 kW.

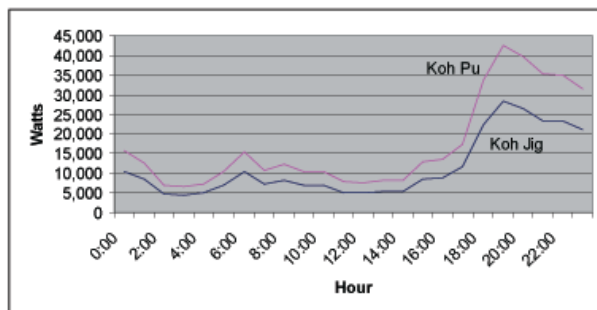


Figure 3: Load profile of Koh Jig and Koh Pu (estimated 1.5 times of Koh Jig)

The results from the two techniques are surprisingly similar: 419 kWh (bottom-up) and 412 kWh/day (comparative study with Koh Jig). These similarities notwithstanding, experience in electricity forecasting in general suggests that estimating future demand with a high accuracy is impossible. In hybrid system modeling, therefore, we consider three scenarios with future demand at a “base case” of 410 kWh/day and also “high” and “low” scenarios of 125% of base-case and 75% of base-case demand, respectively.

Electricity demand growth beyond these scenarios is possible. One possible source of high growth could be a large number of guest houses or bungalows, especially if they used air conditioning. But the village lacks a sandy beach, presenting somewhat of a constraint to future tourism development. Perhaps a more potent source of high electricity demand could arise from air conditioning in households. Currently no air conditioning is used. If we assume 20% of the households purchase (12,000 BTU/hr) air conditioners, the energy demand would greatly increase to 180% of the base case. The use of air conditioners would also require the generator to operate all night. In Koh Jig, the situation was explained to the community and the community reached a consensus decision that air conditioners were not allowed. We would encourage Koh Pu to reach a similar decision.

Another key appliance to target is rice cookers. On Koh Jig rice cookers are allowed, but contribute significantly to evening peak load since each rice cooker consumes 500 to 1,000 watts and takes about half an hour to cook. High electricity tariffs mean that a single rice cooking consumes four to eight baht of electricity. LPG-fired rice cookers or even solar ovens should be promoted.

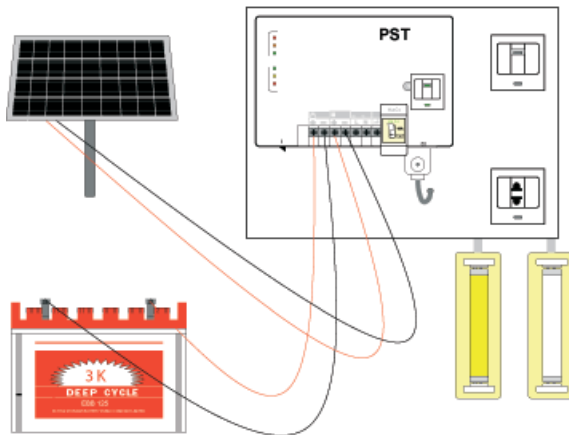
### Technical evaluation of existing electricity generation

Currently, electricity for the village of Koh Pu is produced in primarily two

ways: (1) most homes have individual solar home systems donated by a Thai government program that provides limited electricity for lights and TV; (2) UNICEF donated two 30 kVA diesel generators that are turned on every evening to provide electricity to the village. In addition, some households have small privately owned diesel or gasoline powered generators (now seldom used). The Koh Pu school has a 5 kWp solar electric system.

### Solar Home systems & school system

The majority (128 out of about 150) homes on Koh Pu have solar home systems, which were installed in May/June 2005. The households ineligible for solar home systems were those that did not have correct household registration papers at the time that the SHSs were installed. Some of these households now have correct paperwork and have asked for a SHS, but have not yet received them. For homes that have received them, the SHSs provide limited electricity for lighting (two 10-watt bulbs) and an hour or so of TV per night. Each system comprises a 120 watt peak panel, a 150 watt inverter/charge controller, a 125-Ah 12-volt battery, and two 10-watt fluorescent lights. All equipment is assembled or manufactured in Thailand. The solar module is assembled by Solartron Public Company Limited.<sup>1</sup> The inverter is manufactured by Power Solutions Technologies.<sup>2</sup> The battery is manufactured by Thai Storage Battery Ltd. Public Company Limited (3K).<sup>3</sup> Total energy production from the solar panel is about 350 to 450 watt-hours/day. Maximum power output is limited by the inverter's capacity to about 150 watts.



**Figure 4:** Solar home systems comprise a 120 watt solar module, a 125-Ah 12-volt battery, and a combination inverter/charge controller. Maximum power output from the system is 150 watts

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1 [www.solartron.co.th](http://www.solartron.co.th)  
2 [www.pst.co.th](http://www.pst.co.th)  
3 [www.3kbattery.com/](http://www.3kbattery.com/)

Of the 128 solar home systems installed on Koh Pu, at least 26 have failed.<sup>4</sup> The most common reason for failure is the inverter/charge controller. When the inverter portion of the system fails, the user is not able to use AC electricity. Sometimes users abandon the system. In other cases, they purchase an external inverter (sold in Krabi) to convert DC electricity to AC. When the charge-controller function of the unit fails, electricity no longer passes from the solar module to the battery. In this case, many users bypass the (broken) charge controller by charging the battery directly with the solar module. This tends to overcharge the battery in many cases, leading to excess water consumption. Unless the user is vigilant about keeping the electrolyte level in the battery sufficiently high (by adding distilled water), the battery plates quickly become exposed and the battery soon fails.

From observation, about 1/3 of the SHSs in Koh Pu were installed with the solar module in a shaded location. Even moderate shading leads to significant power reduction. As a result, these systems are performing poorly, and it is likely that the (undercharged) batteries will prematurely fail under normal appliance loads. This will especially be the case in the rainy season (June – October).

Importantly, it appears that very few of the solar modules (solar panels) have failed. Though it was impossible to visit every system during the time on the Koh Pu, the team saw not a single system with a failed module.

A study of 405 Thai solar home systems completed in June 2006 in Tak Province (which use the exact same solar panel and battery, but a different inverter) found that 22.5% of the systems had broken down within approximately one year, and that charge controller/inverter and lamp ballast deficiencies were the most likely sources of failure. Solar panel faults were only found in 0.7% of systems (Table 4). Many of the solar panel failures observed in the Tak Province study were due to quality control problems inside the junction box, including missing connectors and diodes wired with incorrect polarity. These are field-repairable. It is reasonable to assume, based on observations in Koh Pu and based on research in Tak province that at least 95% of SHS solar panels are technically fit for re-use in a collective hybrid system.

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<sup>4</sup> We received this data from Khun Ton at the Save Andaman Network (SAN). Khun Ton noted that he thinks that the number is too low since he could not find his friend's name on the list and he knows that his friend's SHS is not working.

Broken Component	No. of broken systems	%
Solar Panel	3	0.7%
Battery	24	5.9%
Charge Controller / Inverter	41	10.1%
Ballast / Lamp	39	9.6%
<b>Overall system failure</b>	<b>91</b>	<b>22.5%</b>

**Table 4:** Individual component and overall system failure rates, based on a survey of 405 solar home systems in Tak province. Solar panels and batteries are exactly the same as those in the Koh Pu and Koh Po systems. Source: Lynch, A., C. Greacen, et al. (2006). "Threatened Sustainability: the Uncertain Future of Thailand's Solar Home Systems." [www.bget.org](http://www.bget.org)

While it makes sense to re-use the solar panels, the batteries in existing SHSs should not be re-used in a hybrid system for several reasons: (1) it is standard industry practice to use large capacity 2 volt (or at most 6 volt) batteries in series/parallel. These larger batteries have longer life expectancies because of fewer and larger materials (plates, connections between cells). Second, based on experiences in Tak, many of the shaded SHS installations have batteries that are already sulfated (from lack of sunlight to the solar panel). Mixing sulfated batteries with OK' batteries is heavily discouraged because the sulfated batteries degrade the performance of the collective battery bank.

The school system has 5 kW of solar modules and a 2 kW inverter from Leonics and it appears to be working. Though the team did not survey the school, it is likely that the system currently produces power in excess of the school load.

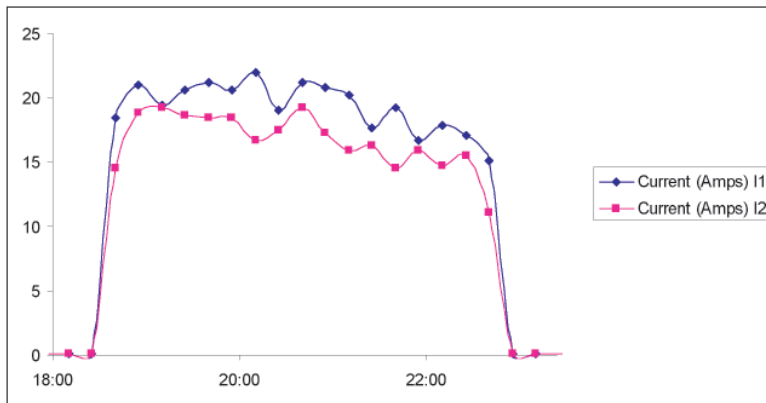
### **Diesel generators**

The UNICEF generators (30 kVA, 50 Hz) appear to be working fairly well. After about 3 months of use one of the generators' radiator leaked, but the villagers were able to get it fixed. In general, however, villagers expressed concern that they do not know who to turn to when generators break down.

Both UNICEF generators in Koh Pu were not effectively utilized in the sense that only two of the three phases were in use, the third phase was completely unused (see Figure 5). The village technician was unaware that there was a third phase that could be used.

Of greater concern is the condition of the distribution system. The distribution system on Koh Pu uses two-conductor 2.5 mm copper wires, with indoor-rated insulation. These wires are simply inappropriate for a distribution system of this type. On the one hand, the insulation on the wires is only rated for indoor use and prolonged exposure to UV sunlight and rain will destroy the insulation, leading to short-circuits, presenting a considerable fire hazard. On the other hand, the conductor size is too small considering the magnitude of the electrical current transmitted along with

the distances. This leads to excessive power loss in the wiring. An entirely new distribution system is necessary on Koh Pu built to reasonable standards found elsewhere in rural Thailand. (The distribution systems in Koh Jig or Koh Po discussed elsewhere in this paper are suitable examples.)



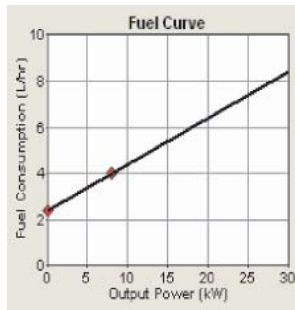
**Figure 5:** At Koh Pu only two of the generators’ three phases were used leading to generator unbalance.

### 2.3 Evaluation of current system on Koh Pu: sustainability, costs and environmental impact

The most significant issues regarding the sustainability of the existing electricity arrangements are (1) ongoing technical sustainability of the system; (2) fuel expenses. So far the diesel generators have worked well, but there is limited local knowledge on operation and maintenance (O&M) and villagers are concerned that if the generators break down they do not know who to contact. Similarly, PV SHSs are starting to fail in significant numbers, and failure rates will likely increase substantially in the rainy season because lower light levels will lead to an energy deficit and subsequent sulfation. Currently, the tariffs that are collected are sufficient to cover the cost of diesel fuel only (with a small amount for the local technician). No funds at all are collected to address future needs for equipment replacement and repair.

Costs to villagers related to the diesel generator will largely be determined by future diesel fuel costs. Currently diesel fuel costs 33 baht/liter, several baht/liter higher than on the mainland. Diesel consumption at Koh Pu’s primary generator is approximately 0.47 liters/kWh, (15 liters/day for daily generation of 32 kWh). While we were not able to obtain a “no load” fuel consumption figure, we assumed a typical value of 0.08 liters/hr-kW rated output or 2.4 liters/hr for the 30 kVA generator (source: HOMER default

values). Together these imply a fuel consumption curve as shown in Figure 6 below. Considering that about 40 households are connected to generator #1, this implies a monthly “fuel cost” per household of about 340 baht (at current fuel prices).



**Figure 6:** Derived fuel consumption curve for IVECO 30 kVA generator used on Koh Pu.

Solar home systems have zero fuel costs and nearly zero operations costs in the short term, but based on experiences in Tak province with similar systems, the long term costs (factoring in necessary replacements of equipment such as batteries and inverters over time) is estimated at 130 baht to 300 baht per household per month.

Potential key environmental impacts from the diesel generator include noise, particulate air pollution, and the risk of diesel spills. Noise was not mentioned as a key concern in Koh Pu and the generators appear to be located sufficiently far from homes that few, if any, are negatively affected. Risk of diesel spills is substantial, as the fuel must be brought by boat from the mainland, offloaded by hand, and pushed by hand-cart to the generator.

Environmental impact from the PV SHSs is fairly low. The largest concern is the recycling of the lead-acid batteries. Koh Pu villagers report that they already sell dead batteries several times per year to a materials recycler that comes to the island.

### **Technical concept for the future PV Hybrid system**

The proposed future hybrid system has several goals:

- To increase the electricity service quality available to villagers (such as 24-hour power, allowing use of refrigerators, as well as power tools, etc. – with high reliability)
- To lower the costs to villagers through a more efficient use of the diesel generator (running at more optimal capacity), and through more effective use of existing solar panels.
- Flexibility to allow expansion as island electricity loads grow
- To serve as a structured opportunity to build local technical and managerial capacity

Broadly, the idea of the hybrid system is to pool all the energy sources into a single integrated mini-grid. Pooling electricity allows energy supply to be shared collectively so that larger loads can be served for a lower cost. Combining renewable energy with conventional diesel generation lowers costs by using renewable energy when available, but maintains reliability through fossil fuel power when the sun is not shining or the wind is not blowing hard enough to power village loads.

### **Hybrid system optimization modeling methodology**

Designing optimized hybrid systems involves careful consideration of dozens of variables including:

- the village electricity load profile (kW for every hour of the day)
- location-specific solar resource (taking into account that some days are cloudy and some are sunny)
- location-specific wind resource (monthly averages, diurnal variation)
- physical characteristics of batteries considered (capacity and voltage, cycle life, round-trip efficiency, minimum state of charge, lifetime throughput, maximum charge rate and maximum discharge rates)
- physical characteristics of solar panels (derating factor, slope, lifetime)
- physical characteristic of generators (output vs. fuel consumption curve, minimum load ratio, lifetime operating hours)
- physical characteristic of wind turbines (power curve)
- diesel fuel price
- initial, O&M and replacement costs of all components

The optimization and simulation tasks involve answering the questions, “Which components does it make sense to include in the system design?”, “How many and of what size each component should be used?” and “What will be the total costs involved?” The large number of technology options and the variation in technology costs and availability of energy resources make these decisions complex.

To determine optimum component sizes, the team used “HOMER: The Micropower Optimization Model”, developed by the US National Renewable Energy Laboratory. HOMER simulates the operation of a proposed system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER<sup>5</sup> compares the electricity demand in the hour to the energy that the system can supply in that hour, and then calculates the flow of energy to and from each component of the system. This requires an hour-by-hour simulation of the solar and wind power available, as well as hour-

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<sup>5</sup> HOMER is available for free download from: <http://www.nrel.gov/homer/default.asp>.

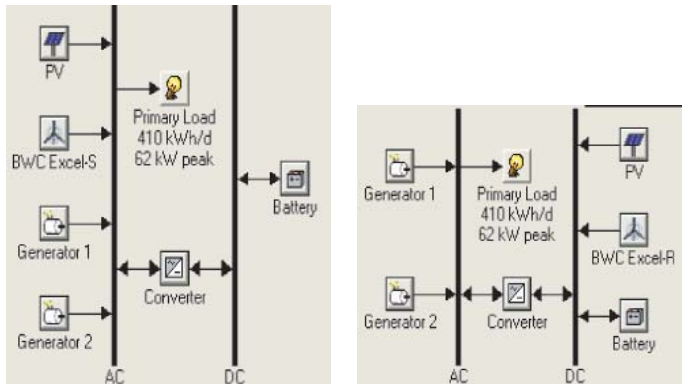
by-hour estimation of the electricity load. HOMER also decides for each hour on how to operate the generators and whether to charge or discharge the batteries.

HOMER performs these energy balance calculations for each system configuration that the software user specifies. Because we consider a range of different capacities for PV, batteries, and inverters on Koh Pu, there are thousands of different system configurations considered. HOMER then determines whether each configuration is feasible, i.e., whether it can meet the electric demand under the conditions that you specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest. After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost).

### **System architecture**

Hybrid systems are fundamentally of two types: direct current (DC) bus and alternating current (AC) bus. The key difference between the systems is that in a DC bus system, all electricity from renewable energy sources must be produced nearby the battery bank (located in the power house). In an AC bus system, electricity generation can occur anywhere along the AC transmission system. Thus, solar panels can be distributed in several different locations in the village. For this reason, AC bus systems are considered to be more flexible and expandable. AC systems are a newer technology, but there is already one AC bus project in operation in Thailand (at Koh Jig, discussed elsewhere in this study) which has been performing well. The company (SMA) which has developed the equipment to do this has been very responsive in ensuring rapid technical support to minimize downtime from technical problems.

Recognizing the importance of future expandability, the systems modeled in this study are AC bus systems. We do not consider the DC bus option. DC systems would, in general, be slightly less expensive and would perform similarly, but be less flexible for future expansion.



**Figure 7:** AC bus system (on the left) has renewable energy sources connected directly to AC lines that go to throughout the village. In a DC bus system<sup>6</sup>(diagram on right) renewable energy resources are connected to the DC bus, which is located only inside the powerhouse.

### Key Koh Pu model input assumptions

The “optimal system” determined by HOMER depends on the input assumptions. Key assumptions are summarized in the table below, and followed by a more detailed discussion.

Variable	Value	Data source	Notes
Interest rate	6%		
Fixed costs	Fixed O&M \$4,500 per year. Fixed capital cost \$ 81,250	Koh Jig experience	(technician salary + power house, transmission line, installation fee)
PV cost	20 kW for \$16,280 30 kW for \$63,890, with linear increase for subsequent PV	PV cost estimated at \$3.9 per watt (Leonics Jun06) + cost includes cost of Sunny Boy inverter (SMA quote).	First 20 kW recycled, and need only grid-intertie inverter.
Solar resource	5.04 kWh/m2/day	NREL dataset	
Wind turbine cost	10 kW for \$66,000	Koh Jig installation	Uses Excel BWC S power curve (XLS)
Wind resource	Annual average 3.67 m/s with monthly variations	E for E study – data for Satun Province	Should be considered a rough estimate only.
Generator #1	30 kW initial cost \$0.		Existing generator

<sup>6</sup> In order to model AC bus systems, it is necessary to use version 2.2 Beta (or later) of HOMER.

Generator #2	Sell existing 30 kW for 80,000 baht. Subsequent purchase of 60 kW for \$15,800. Linear interpolation for other sizes	Bangkok IVECO representative estimates	Generator #1 and #2 cannot operate simultaneously
Diesel cost	\$0.86/liter (33 baht/liter)	Village interview	
Converter (inverter)	13.5 kW for \$14,666. Other size costs by linear interpolation	SMA quote for three 4.5 kW "Sunny Island" units	Note – same inverter in Koh Jig costs \$21,050 including tax and shipping
Battery	Hoppecke 12 OPzS. 30 cells cost \$19,452. Other sizes determined by linear interpolation.	SMA quote.	Each cell is 2 volt, 1200 Ah. In actual practice the installation will need batteries in multiples of 30 (because it is a nominal 60 volt system) and therefore may need sizes other than 1200 Ah.

**Table 5:** The ‘Optimal System’

The sizes considered for each component are shown in Figure 8. These sizes were iteratively determined to be sufficiently broad that HOMER did not indicate that the “search space” of any particular item was possibly too small, while at the same time trying to reduce the number of possible options in order to keep the computational requirements, and thus model run time, at a manageable level.

PV Array (kW)	XLS (Quantity)	Gen1 (kW)	Gen2 (kW)	Batteries (Quantity)	Converter (kW)
0.000	0	30.00	0.00	0	0.00
20.000	1		30.00	40	10.00
25.000	2		40.00	50	13.50
30.000			50.00	60	17.00
40.000			60.00	70	20.00
50.000			70.00	80	
				90	
				100	
				110	

**Figure 8:** sizes considered for components in Koh Pu HOMER model run. XLS refers to the wind turbine.

### Fixed costs

Building a hybrid system on Koh Pu requires a new distribution system, a power house, and other costs that are roughly independent of the electricity generation and storage equipment chosen. These costs are estimated based on the costs of the Koh Jig hybrid system, adjusted by the number of households’ ratio in each village:

Item	Cost (baht)
Electrical distribution board	450,000
Control room	900,000
Electrical distribution system	1,500,000
Installation, etc.	400,000
<b>TOTAL (baht)</b>	<b>3,250,000</b>
<b>Total (\$US)</b>	<b>\$81,250</b>

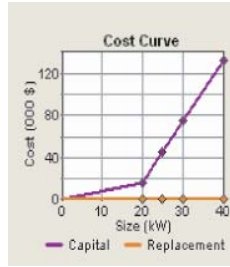
**Table 6:** Fixed Costs. Koh Pu

In addition, the project incurs fixed O&M costs: labour for one technician 7,000 baht/month or about \$4,500 per year. (These figures are based on actual costs for Koh Jig).

### **Solar PV**

Where possible, all PV modules from the existing solar home systems and other installations on the island would be utilized in the hybrid system. Of the 128 solar home systems, we assume that 125 are usable (not damaged). This assumed failure rate of 2% is consistent with observed failure rates of 0.7% described in the “Technical evaluation of existing electricity generation” section above. The “Sunny Boy” inverters considered in this modeling exercise work at highest capacity with a nominal 300 volt DC system voltage. Since the nominal voltage of each solar module is 12 volts, this requires modules be installed in series strings of 25 modules each. Assuming that 125 modules are available, this implies 5 series strings. We also assume that it is possible to use the 5 kW now installed at the school.

In the HOMER modeling, the costs of solar PV panels are complicated by the fact that the first 20 kW (15 kW from SHS + 5 kW from school solar electric system) are “free” in the sense that they are recycled from existing projects on the island. They are not entirely free, however, since their use requires expenditures for inverters (to convert their output to ac electricity) and (in the case of SHSs) for new mounting structures. Based on a quote from SMA (see table 5), the inverter is estimated to cost \$614 per kW. The mounting structure estimated at \$200 per kW. Taking into account these amounts the first 20 kW of PV costs about US\$16,000. Additional purchases of PV, actually purchasing the modules, as well as inverter & mounting structure costs, are therefore considerably more expensive (Figure 9).

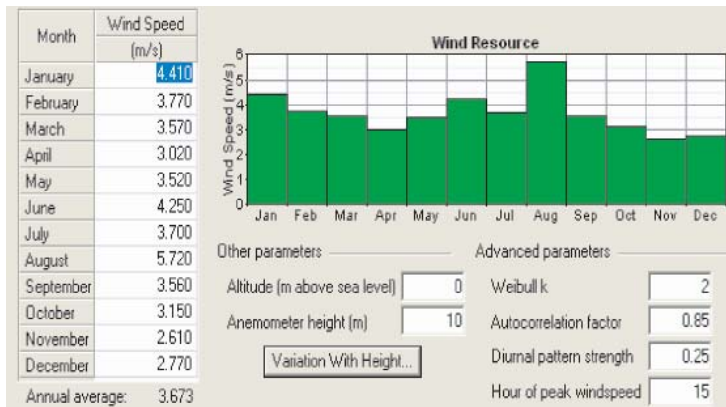


**Figure 9:** Cost curve of solar electricity for Koh Pu. Replacement cost is irrelevant as no PV is replaced in the time period covered in the analysis (PV life and project life are both set at 20 years).

Solar data used in the modeling is downloaded through HOMER from the internet specifically for the latitude and longitude of Koh Pu from a global database maintained by NREL. The scaled annual average insolation is 5.04 kWh/m<sup>2</sup>/day.

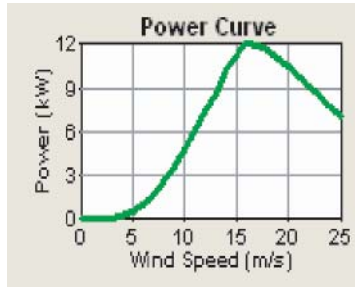
### Wind power

The wind resource is much more site specific than solar, and therefore can only be specified satisfactorily with a multi-month anemometer data logging effort. Wind data for this initial modeling (Figure 10) is based on a wind data from Haat Ra Wai, in Satun Province. Satun province is adjacent to Krabi province to the south. Like Koh Pu, the location is also a beach area on the Andaman Sea. Modeling should ultimately be re-done with better wind data.



**Figure 10:** Wind data assumptions used in HOMER modeling of Koh Pu. Source for Haat Ra Wai data: Fellow Engineers (2004). Wind Energy: study on investment cost and subsidy based on real resources and statistics (in Thai). Study to support solar and wind power. Bangkok, E for E Foundation.

Installation of large wind turbines is complicated by the need for a large crane, which is logistically challenging considering the small piers on Koh Pu. For this reason, we consider turbines no larger than 10 kW which can be erected using a gin pole and winch. The turbine considered is a Bergey BWC Excel-S ([www.bergey.com](http://www.bergey.com)). Installed turbine cost is estimated at \$66,000 based on the cost of installation of 10 kW turbines at Koh Jig.



**Figure 11:** Power curve of Bergey BWC Excel-S used in wind power output calculations. Source: [www.bergey.com](http://www.bergey.com)

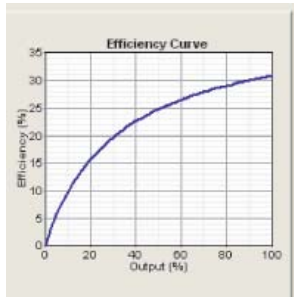
### Diesel

The hybrid system will rely on diesel generators to provide power when renewable sources are not available, and to charge batteries if power is available and the batteries need charging.

There are two identically sized 30 kVA diesel generators already installed by UNICEF on the island. The expected future peak load will exceed what one of these generators can generate. There are several options:

1. Sell one of the generators and purchase a larger one.
2. Sell both generators and purchase a larger one.
3. Keep both generators and synchronize them so they can operate simultaneously on the same AC bus
4. Use the two generators, but with separate transmission systems (making two AC buses)

Options 1 and 3 are attractive from a fuel-savings perspective. Generators perform at lower efficiency under partial load (Figure 12). With two generators, if load is small only a single smaller generator can be used. If load is higher, a larger generator (or possibly both) can be turned on.



**Figure 12:** Efficiency curve for generic 30 kVA diesel generator. Source: HOMER

Simultaneous operation of generators on the same AC bus requires synchronization. Synchronization of the generators (option #3) is discussed in the attachment. Synchronization of small scale generators like these is not common practice. It is probably possible to synchronize these generators, but at substantial cost (about \$7,000). It may be possible to synchronize manually, but considering that synchronization would have to be done frequently (every time that demand exceeded a single generator) and that the consequence of incorrect timing during synchronization could be a broken machine, we recommend further study is necessary to determine whether it is viable.

Option 4 adds considerable cost, as having separate AC buses requires three additional “Sunny Island” inverters (one for each phase). It also means that if there is an energy surplus on one AC bus and an energy deficit on the other that electricity will have to make a full AC – DC – AC transition, losing about 20% to 30% of the energy in round-trip conversion inefficiencies.

Overall, we recommend option #1 (selling one generator and purchasing a larger one). This option saves considerable fuel by reducing run-time at partial load. At the same time, however, it avoids the necessity of synchronization. In the future if load grows beyond the capabilities of either generator alone, option #1 allows the possibility of synchronization if it turns out to be a technically viable option. Based on a verbal quotation from the IVECO generator representative in Bangkok, a new 60 kW generator costs 600,000 baht (\$15,790). After further discussions with generator professionals, we expect the existing 30 kW generator has a resale value of 80,000 baht (\$2,100). O&M costs are estimated at \$1/hour for a 30 kW generator and \$1.5/hour for a 60 kW generator. Generator lifetime is 15,000 hours.

In the HOMER modeling, we allow consideration of two generators, but do not allow them to operate simultaneously. Generator #1 capacity is fixed at 30 kVA (existing UNICEF generator). Generator #2 capacity is chosen by HOMER.

### Bi-directional Inverter (Converter)

In the hybrid system the bidirectional inverters change electricity from AC to DC to store in the batteries, and then back again as necessary to optimize use of the diesel generator. The modeling assumes three (one for each phase) SMA “Sunny Island” inverters, which are 90% efficient in changing electricity from AC to DC, or from DC to AC.

Cost assumptions for the inverters are based on a quote from SMA (see attachment). Costs are assumed to be linear with capacity.

The PV inverters (one SMA “Sunny Boy” inverter for each of the systems’ three phases) to connect PV modules to the AC line are considered separately, as discussed in the solar PV section above.

### Batteries

The system requires a certain amount of energy storage to make optimum use of solar energy and limit generator run time. The batteries considered are large two-volt industrial lead-acid batteries manufactured by Hoppecke. Costs based on a quote from SMA (see table 5) are \$19,452 for thirty 2-volt cells, each 1,200 Ah (42.1 kWh) of storage. Costs are assumed to be linear with increasing kWh storage.

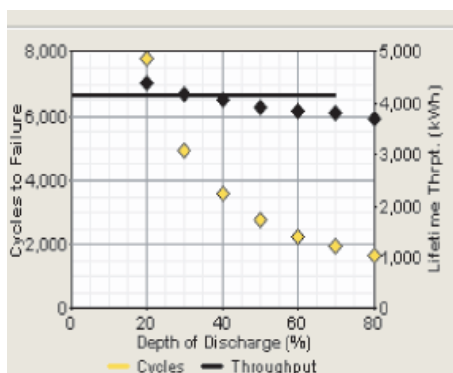


Figure 13: Battery cycles until failure (yellow) and lifetime throughput (kWh) as a function of depth of discharge. HOMER uses this data to determine the capacity of the battery bank (in kWh) that will lead to lowest overall cost of energy – taking into account that excessive discharge will require more frequent battery replacement.

### Biogas/biomass

There are several technological options for using biomass that work particularly well with existing diesel generators that are possibilities for Koh Pu: biogasifier, biodiesel, and biogas (methane). Several of these options could be pursued in parallel (e.g. biogasification and biodiesel). At this point there is insufficient data on biofuels possibilities. While the options are discussed below, they were not modeled at this stage in HOMER.

**Biogasification** involves combustion of biomass fuel in a low-oxygen environment to produce carbon monoxide-rich producer gas. The producer gas can be burned (either alone or mixed with diesel fuel) in a generator. If a regular diesel generator is used (like the one in UNICEF) it is necessary to have at least 30% fuel from diesel to ensure proper combustion. For generators designed for natural gas it is possible to run 100% on producer gas. In Battambang Cambodia a community cooperative powers a 7 kW generator using fast-growing, nitrogen-fixing leuceana/gliciridia grown on 4 hectares of local land and producing about 15 Tons (dry material) per hectare per year. The trees are not chopped down. Rather, they are coppiced so that new branches can grow back, a 7 kW generator runs about 6,000 hours a year (16 hours/day)<sup>7</sup>. A convenient rule of thumb is that in the case of 6,000 hours per year generator operation and 20 tons per ha. per year production, one ha. supports about 2 kW. Powering the entire Koh Pu village from biofuels would take roughly 20 hectares of leuceana/gliciridia, or about 125 rai (using the Thai measurement system)<sup>8</sup>. Koh Pu is roughly 3,000 rai, so this represents about 4% of the total land area. Fortunately, after an initial nursery period of 3-4 months leuceana can be transplanted to dry open fields. The plant is sturdy with a deep tap root so it can survive dry seasons without irrigation. The “ANKUR” brand gasifier is produced in Sri Lanka.

The cost of the biogasifier used in the Cambodian village (not including generator, civil works, shipping, or taxes) is about US\$5,000. Necessary civil works include a concrete platform with foundations, a small cooling pond (2 X 3 meters about 1.5 m deep). The total cost in Cambodia (not including generator) was about US\$12,000 including taxes, transportation and duties.

**Biodiesel using coconuts** is another technology sometimes suitable for remote islands. Coconut oil can be converted to biodiesel through a transesterification process involving mixing sodium hydroxide and ethanol to the coconut oil. Or, in some cases, coconut oil can be burned directly in diesel engines. This makes sense only if the price of coconut oil locally produced is significantly lower than the cost of diesel<sup>9</sup>. Unfortunately, it appears that there are few coconut trees on the island.

Finally, **biogas methane** from anaerobic digestion can be an appropriate fuel for generators. Generally this fuel is not mixed with diesel. Rather, engine modifications are required (addition of spark plugs, sulfur filtration system and/or expansion of lubrication oil reserves and frequent oil changes to address higher acidity arising from presence of hydrogen-sulfide). Biogas

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7 Personal communication, Tony Knowles, advisor: SME Cambodia. The group is available to do a detailed feasibility if needed. Contact: tknowles@forum.org.kh

8 1 rai = 0.16 hectares

9 An excellent paper on this topic is: Cloin, J. (2005). “Coconut Oil as a Biofuel in Pacific Islands -- Challenges and Opportunities.” South Pacific Applied Geosciences Commission. [http://www.sopac.org/tiki/tiki-download\\_file.php?fileId=520](http://www.sopac.org/tiki/tiki-download_file.php?fileId=520)

requires a constant high-Biochemical Oxygen Demand (BOD) waste-stream. Livestock farms, breweries and agricultural processing facilities often have appropriate waste. Cellulose waste (most plant leafy material) is much more difficult to digest.

The team discussed biomass and biogas with the community. Together, we were unable to identify a large enough source of biomass on the island that could serve as a sustainable fuel source. However, because producer gas and biodiesel can both be mixed with diesel fuel and used in an unmodified diesel engine, they are an easy addition to the system and therefore there may be significant opportunities to shave diesel costs with one or more of these technologies, especially if land is available that can be used for biofuels crops. It is possible to use HOMER to consider biofuels-for-diesel substitution, but a complete biofuels survey is necessary to determine the extent to which the biofuels discussed above are a viable option.

## 2.4 HOMER Modeling results for Koh Pu: optimal system configuration and costs

Figure 14 below shows the results from HOMER modeling for Koh Pu.<sup>10</sup> The modeling simulates 8,760 hours (one year) of operation and thousands of different system configurations. The system with the overall least cost of energy is the one highest on the list. The first six columns of the HOMER results table shows graphic icons representing which components are present in the optimized system. The remaining columns show the optimized capacity of each component, the initial capital cost, the total net present cost, the cost of energy (in \$ per kWh), renewable energy fraction, total liters of diesel consumed per year, and the number of hours that each generator operates.

						PV (kW)	WLS	Gen1 (kW)	Gen2 (kW)	Batt. (kWh)	Conv. (kWh)	Drip. Stgy.	Initial Capital	Total NPC	COE (\$/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)	Gen2 (hrs)
						20		30	50	40	10.0	CC	\$ 145,379	\$ 723,848	0.422	0.19	41,523	3,734	1,030
						20	1	30	50	40	10.0	CC	\$ 211,379	\$ 787,471	0.459	0.22	40,094	3,670	990
						20		30	50	40	10.0	CC	\$ 129,099	\$ 837,862	0.488	0.00	51,111	5,143	1,051
						20		30	60			CC	\$ 111,210	\$ 885,428	0.516	0.17	56,203	6,016	2,036
							1	30	50	40	10.0	CC	\$ 195,099	\$ 897,075	0.523	0.03	49,328	5,011	1,009
								30	60			CC	\$ 94,930	\$ 924,063	0.538	0.00	60,444	6,720	2,040
						20	1	30	60			CC	\$ 177,210	\$ 956,431	0.557	0.20	55,265	5,949	2,018
							1	30	60			CC	\$ 160,930	\$ 998,250	0.582	0.04	59,564	6,734	2,026

Figure 14: Results of HOMER modeling for Koh Pu under base-case assumptions. The first system in the list is the optimal system for the base-case scenario.

<sup>10</sup> The best way to investigate the HOMER results (and to view consequences of different assumptions) is to use HOMER directly. The data file for Koh Pu is available at: [www.palangthai.org/docs/KohPu.hmr](http://www.palangthai.org/docs/KohPu.hmr).

Based on the HOMER modeling, the optimal system for Koh Pu is a hybrid solar/diesel system (no wind power), with 20 kW of solar, a 50 kW diesel generator #2, 96 kWh of batteries, and 10 kW bi-directional inverter. This “optimal” system uses 19% renewable energy, and the cost of electricity is \$0.422/kWh (about 16 baht/kWh) including depreciation on capital and leveled O&M costs.

The initial capital cost for this system is estimated to be \$145,379 with the “other” (distribution system and power house) being the single largest cost (Figure 15) . Diesel expenditures over the projects 20 year lifetime mean that the net present cost is largely dominated by generator costs (72% of total costs).

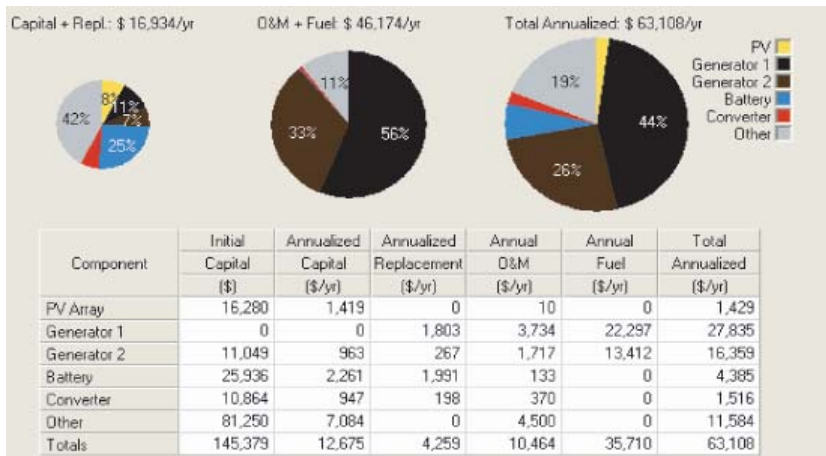


Figure 15: cost breakdown of optimized Koh Pu system

If a wind turbine is added (system shown in Figure 14 second row), then battery, PV and generator #2 capacities remain the same, however the cost of energy increases significantly – by about \$0.037/kWh.

### Comparison with “diesel only” for Koh Pu

In order to supply the same 24-hour electricity service using only diesel generators, (Figure 14 ) indicates that optimal “diesel only” system would require a 30 kW and 60 kW generator, with the 30 kW operating 6,720 hours/year and the 60 kW operating the remaining 2,040 hours/year. In this diesel-only case the cost of energy is \$0.538/kWh with a net present cost of \$924,063. (By comparison, the tariff currently charged for electricity is 25 baht/kWh (\$0.67/kWh)). In contrast, the optimal hybrid solution discussed above provides electricity at \$0.422/kWh with a net present cost of only \$723,848. The optimal solution thus saves the difference of about \$100,215 over the lifetime of the project, compared to an optimized “diesel only” option providing the same level of electricity service. The “diesel only”

option produces 159 tons of CO<sub>2</sub> per year, whereas the hybrid system produces only 110 tons of CO<sub>2</sub> per year.

## 2.5 Estimated costs, sensitivity analysis Koh Pu

The “optimal system” derived by HOMER depends on the assumptions used. Two key variables with considerable uncertainty but high impact on model outcomes are diesel price and projected load. To address this uncertainty, the team performed a sensitivity analysis on each of these variables.

## 2.6 Sensitivity of optimized system design to diesel price

In the base case, diesel price is assumed to be \$0.86 per liter (current prices). In diesel price scenarios, prices are 134%, 163% and 259% respectively, of base-case price. These prices reflect the price in 10 years assuming annual growth of 3%, 5% and 10%, respectively.<sup>11</sup> Hybrid system equipment capacities, initial capital costs, present value costs, cost of energy, and the renewable energy fraction for optimal hybrid systems diesel price sensitivity scenarios are shown below in Figure 16.

The results show that in no scenarios are wind turbines a good investment.<sup>12</sup> Instead, higher fuel prices tend to encourage larger solar array sizes, with higher optimal renewable energy fraction (as high as 34%).





















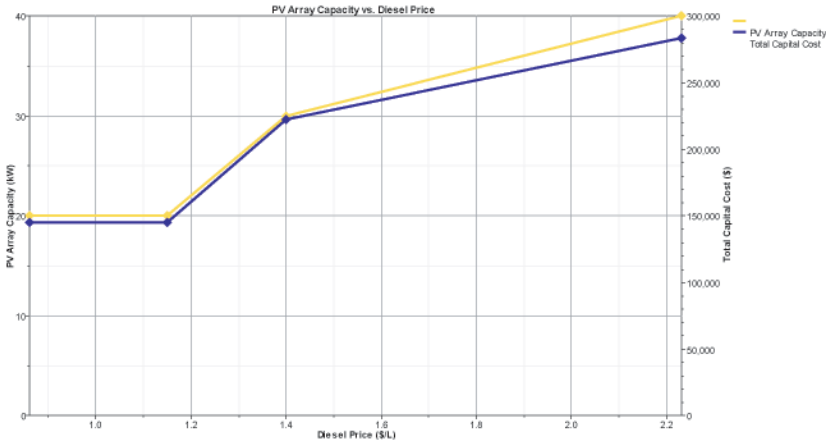
Diesel (\$/L)					PV (kW)	%LS	Gen1 (kW)	Gen2 (kW)	Batt. (kW)	Conv. (kW)	Disp. Stge	Initial Capital	Total NPC	COE (\$/A/Wh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)	Gen2 (hrs)
0.860					20		30	50	40	10.0	CC	\$ 145,379	\$ 723,848	0.422	0.19	41,523	3,734	1,030
1.150					20		30	50	40	10.0	CC	\$ 145,379	\$ 862,104	0.502	0.19	41,528	3,735	1,030
1.400					30		30	50	80	13.5	CC	\$ 222,727	\$ 968,605	0.564	0.27	36,799	2,996	797
2.230					40		30	50	100	13.5	CC	\$ 283,305	\$ 1,309,664	0.763	0.34	34,499	2,880	720

Figure 16: Fuel price sensitivity results in Koh Pu.

<sup>11</sup> A more standard way of dealing with diesel price sensitivity would be to model year-by-year increases. Unfortunately, because HOMER models only 8760 hours (one full year), this is not possible in current versions of the software. The issue of annually increasing fuel prices raises considerable modeling challenges since the “optimized system” would in theory be changing year by year.

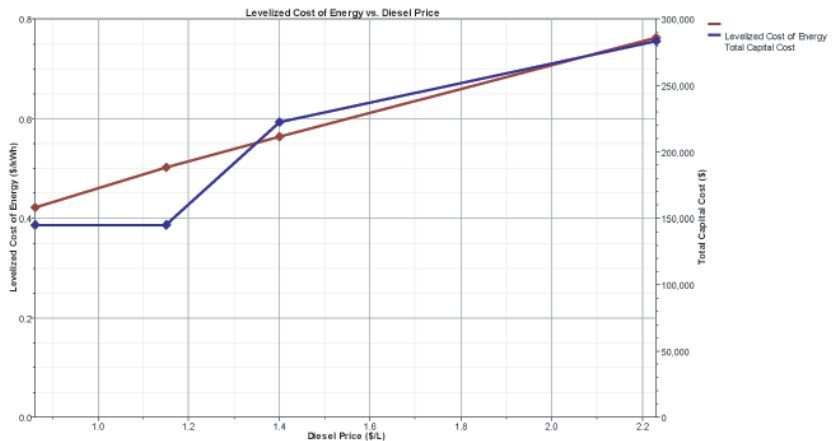
<sup>12</sup> This finding may change with better wind data, or lower cost wind turbines.



**Figure 17:** Graph of optimum PV capacity (kW) and total capital cost as a function of diesel price and forecast load in Koh Pu. Changes in capital cost closely follow changes in PV array capacity, as PV modules are high-capital cost items.

### Cost of energy sensitivity to diesel price – Koh Pu

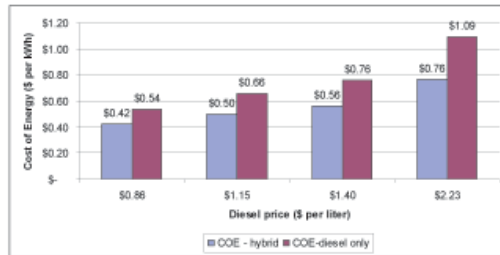
Costs of energy appear to vary in line with diesel prices (Figure 18) – not surprising considering that diesel is the main energy source in the system. Base case cost of energy is \$0.422/kWh if diesel remains at \$0.86/liter. In the highest diesel price scenario (\$2.23/liter) the cost of energy is \$0.76/kWh.



**Figure 18:** Levelized cost of energy (\$/kWh) and initial capital cost of optimum system (\$) as a function of diesel price.

The overall cost savings from a hybrid system compared with a diesel-only option increases with increasing diesel price (Figure 19) because hybrid systems make more effective use of diesel fuel, and substitute increasing

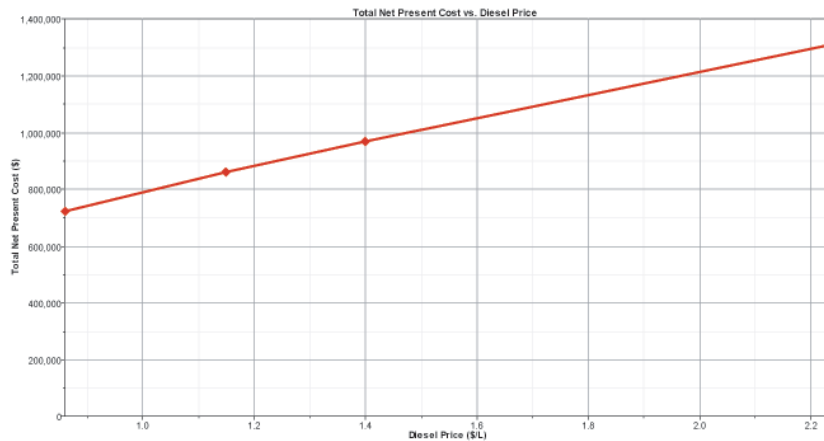
amounts of solar electricity for diesel-generated electricity in scenarios of high fuel prices.



**Figure 19:** Cost of energy (COE) of optimized hybrid vs. diesel-only under different diesel price scenarios.

### Life cycle cost sensitivity to diesel price – Koh Pu

The sensitivity of life-cycle cost (net present cost) to diesel price is shown below in Figure 20, and shows considerable range. Scenarios of high diesel price result in net present cost approaching \$1,300,000, whereas the lowest end scenario is just over \$700,000.



**Figure 20:** Net present cost as a function of diesel price in Koh PU.

### Sensitivity of optimized system design to load forecast – Koh Pu

The base case load is forecast to be 410 kWh per day with a peak load of 63 kW. The sensitivity analysis considers an additional high and low scenario of 125% and 75% of base-case forecast. Figure 21 below shows the results of different load forecasts. The factor affected most is the size of the second generator (generator #2). In low load scenarios, a 40 kW generator is sufficient. In high load scenarios, a 60 kW generator is required. Renewable energy fraction is higher in low load scenarios (with solar electricity picking up more of the daytime load).

Pri. Load (kWh/d)		PV (kW)	XLS	Gen1 (kW)	Gen2 (kW)	Batt (kW)	Conv. (kW)	Disp. Strgy	Initial Capital	Total NPC	COE (\$/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)	Gen2 (hrs)	
410,000				20	30	50	40	10.0	CC	\$145,379	\$723,848	0.422	0.19	41,523	3,734	1,030
307,000				20	30	40	50	10.0	CC	\$149,232	\$566,344	0.441	0.24	28,161	3,562	177
512,500				20	30	60	40	13.5	CC	\$151,812	\$887,854	0.414	0.15	54,115	3,118	1,691

Figure 21: Load forecast sensitivity results in Koh Pu.

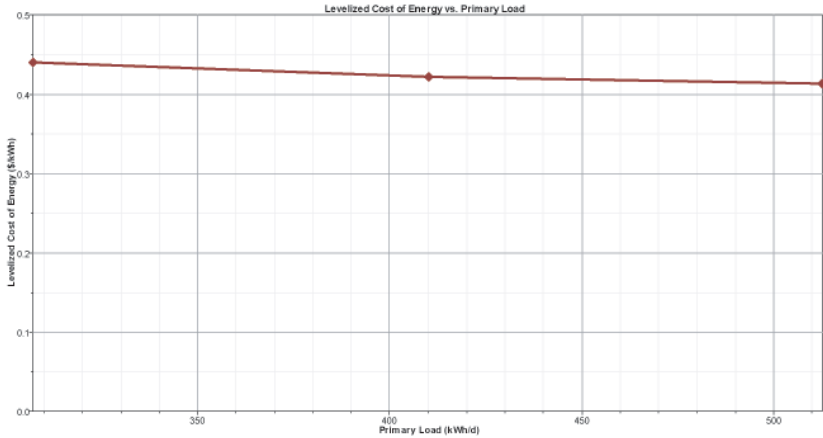


Figure 22: Levelized cost of energy as a function of forecast load in Koh Pu.

Levelized cost of energy is nearly constant for all load growth scenarios, declining slightly in high growth scenarios because of more optimum loading of generators. Under scenarios of low, medium, and high load growth the “hybrid option” remains more cost-effective (lower levelized cost of energy) than the diesel-only option (Figure 23).

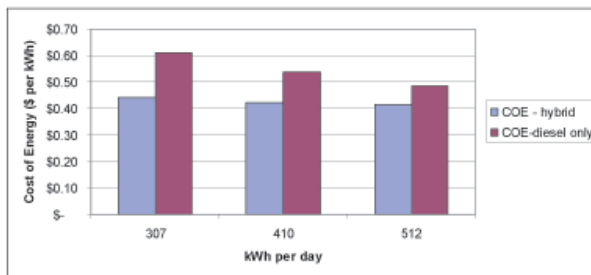


Figure 23: Cost of energy (COE) of optimized hybrid vs. diesel-only under different load growth scenarios.

## 2.7 Koh Pu Summary and recommendations

HOMER modeling results indicate that Koh Pu's electricity needs could be met at considerable overall cost savings with a hybrid (renewable energy/diesel) system compared with existing arrangements (separate diesel generator plus solar home systems).

At existing diesel prices and in a "base case" load scenario, the optimum system comprises a hybrid solar/diesel system (no wind power), with 20 kW of solar, a 50 kW diesel generator #2, 96 kWh of batteries, and 10 kW bi-directional inverter. This "optimal" system uses 19% renewable energy, and the cost of electricity is \$0.422/kWh (about 16 baht/kWh) including depreciation on capital and levelized O&M costs.

Though the optimum system configuration changes under different load growth and diesel price assumptions, the hybrid system remains more cost-effective than the existing arrangements (diesel-only), under all scenarios considered.

Making the transition to a hybrid system from the existing arrangements will require coordination. The suggested step-by-step approach is as follows:

1. Meetings with community to discuss system design and costs, and to re-assess the commitment of the community.
2. Form community ESCO & develop a business plan
3. Identify promising funding opportunities. Submit grant applications.
4. Begin wind monitoring to verify wind data<sup>13</sup>
5. Study biomass options (biodiesel, biogasification, biogas) to supplement diesel
6. Obtain permissions for re-using solar panels, etc.
7. Decide whether or not to sell one generator since only one is sufficient in short term, and likely a larger one will be necessary later.
8. Determine optimum system component sizes
9. Refine equipment specifications once the final size of the system is confirmed.
10. Solicit final bids
11. Develop full bill of materials for system sub-assemblies
12. Order equipment
13. Clear land for power house, PV array, and wind turbines.
14. Build new distribution system
15. Build powerhouse building

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<sup>13</sup> Note: system costs modeled in this study do not include cost of wind data monitoring equipment.

16. Install batteries, inverters
17. Move generator(s) to powerhouse building and connect village directly to generator(s) (to minimize interruption in service).
18. Integrate generators with batteries and Sunny Island inverters
19. Construct solar array rack at suitable sunny location on AC bus
20. Measure short-circuit current ( $I_{sc}$ ) of all solar modules in SHSs
21. Make sorted list of modules, grouping modules of like  $I_{sc}$  together (this step considerably increases overall PV array performance). Install on AC bus using Sunny Boy inverters.
22. Evaluate wind turbine data and order wind turbine if HOMER indicates that wind is favorable with revised cost
23. Monitor increasing power usage and if the capacity of the generator is getting to be too small relative to load growth then sell the existing second 30 kW generator and purchase a larger one.
24. Install wind turbine (if wind and HOMER modeling indicate it is appropriate)
25. Ongoing monitoring and evaluation, technical support from

### 3. Koh Po

The second island considered for a hybrid system is Koh Po. In order to reduce repetition in this study, much of the discussion of Koh Po focuses only on relevant differences between the islands. Though Koh Pu (as discussed above) is an excellent hybrid system candidate, Koh Po is in some ways an even better candidate largely because it already has a good electrical distribution system in place, and a particularly pro-active set of individuals who are enthusiastic about a hybrid system for the island.

#### 3.1 Demographic profile

Koh Po is located 36 kilometers south of Koh Pu. The island has 1,400 Rais (about half the size of Koh Pu). Thirty percent of the land area is made up of rubber orchards. The island has 87 houses as officially registered with the local authority. However, when family members have grown up and started their new families, most have just built the new houses in the same area and conveniently share the same house numbers. The actual number of countable houses is 104. The economy on Koh Po is similar to Koh Pu, depending mostly on fishing. It is estimated that fishing is the primary occupation of 95% of the households, the rest work in rubber orchards. Some do both and household incomes range from 50,000 to 120,000 Baht/year.

#### 3.2 Energy demand and supply assessment

##### Current energy demand

Koh Po and Koh Pu have similar patterns of energy demand. The typical appliances found in most homes are two to five fluorescent lights, a 20" TV, a VCD player, and a fan. An estimation of energy demand for the total 104 households is 116 kWh.

Appliances	Power (Watts)	Number of appliances	Hour of use	Energy demand (kWh)
Fluorescent lamp	18	208	4	14.98
Fluorescent lamp	36	208	4	29.95
TV 21" color	75	104	4	31.20
Stereo	30	104	4	12.48
VCD player	25	104	4	10.40
Fan	35	104	4	14.56
Cloth washer	270	2	4	2.16
Mosque stereo broadcasting	90	1	4	0.36
				116.09

Table 7 Estimated current electrical energy demand on Koh Po

In addition to surveys, the team used a datalogger to record electricity supplied by Koh Poš primary generator on the night that the team stayed on the island. The generator serves 40 households. The data shows the 30 kVA generator turning on at about 6:30pm, with electricity peaking early in the evening from 7pm to 7:30pm at almost 20 kW, and then decreasing to about 15 kW by 10pm. The generator shut off just before 11pm. Average total daily production (the area under the graph in Figure 24 for this generator is 72 kWh.

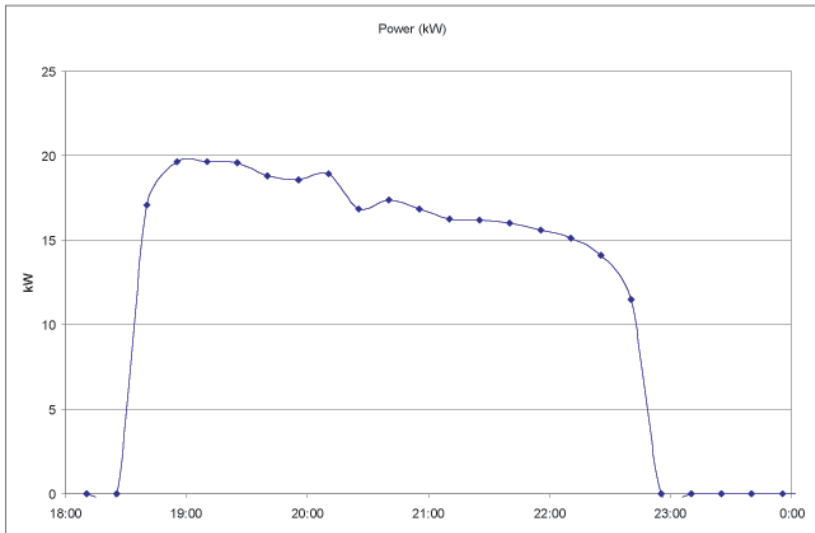


Figure 24: Koh Po electricity demand from generator #1 on 29 May, 2006

### 3.3 Current organizational structure for provision electricity

On Koh Po villagers pay 380 baht/month for an average of 25.5 kWh/month of electricity. That implies a cost of 15 baht/kWh, or about \$0.39/kWh. Currently these costs just cover fuel cost, not depreciation on equipment.

Provision of electricity and other infrastructure development that would improve the well-being of villagers are the responsibility of the village headman. Koh Po has quite a devoted headman and a network of local NGOs that are working for sustainable development on the island. They are quite open to renewable energy technology. In fact, they have been seeking advice from experts and have already identified a suitable site for a wind turbine. Although currently there is no formal organization for the provision of the electricity, with the current people involved in the process, forming an organization for a hybrid renewable energy system should be straightforward.

### **Scenarios for future energy demand in Koh Po**

There are 104 households on Koh Po, and in this sense it is very similar to Koh Jig which has 100 households. Because the economies of the island are similar, we assume that energy demand on Koh Po will closely follow that of Koh Jig. In the base case, three months after the hybrid system begins to operate the demand forecast will stabilize at around 274 kWh per day with peak of 28 kW occurring at around 7:00pm. As with Koh Pu, these assumptions are based on the precondition that significant air conditioning is not part of the electricity load.

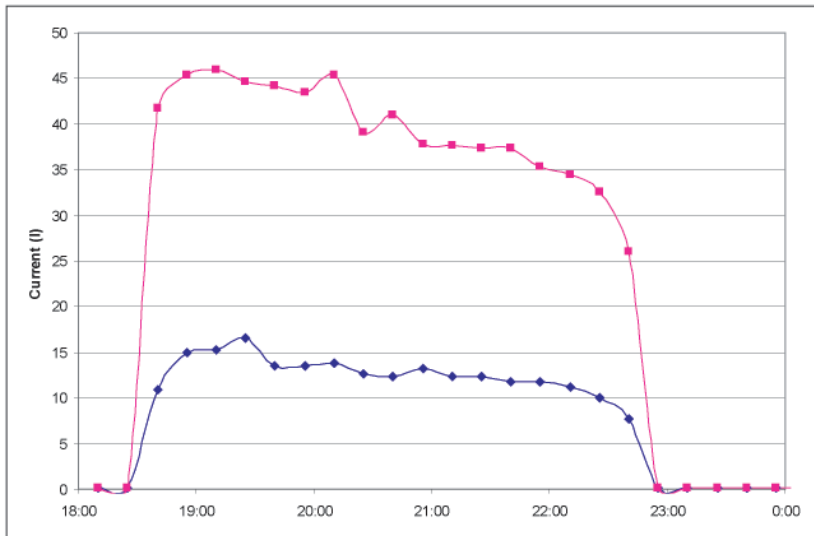
### **Technical evaluation of existing electricity generation**

The current energy supply on Koh Po is a combination of three sources.

- 1) Solar Home Systems: although there are 104 houses on the island, only 87 registered houses received the SHSs from the government. These systems are exactly the same as those on Koh Pu. The villagers have reported that around 80% of the SHSs are broken mostly due to the failed charge controller and inverter. This failure rate seems high in comparison to Koh Pu and it was impossible to determine how accurate this assessment is. The team certainly saw a lot of broken systems. Importantly, however, all solar modules we saw remained working. Currently, the ownership of the SHSs has not been transferred to the local authority yet but they are expected to be transferred by the end of this year according to the government project time frame. Like Koh Pu, the Koh Po school has a 5 kWp solar electric system. The community also has a relatively neglected solar battery charging station of about 1.5 kWp. Several of the modules were broken from reverse polarity accidents, but most looked OK.
- 2) Two diesel generators donated by the UNICEF. The generators provide electricity to most homes on the island in two separate transmission systems, connected to 23 and 40 houses each. Currently, the users pay flat rate electric bill at 400 Baht/month for the 23 houses and 380 Baht/month for the 40 houses. There is a technician overseeing the diesel generators operation and maintenance and billing, receiving only 1,000 baht per month for his service.
- 3) Privately owned diesel generators: there are about 30 sets of the generators which ranges in size from 3-10 HP on Koh Po. The generators are often shared among a cluster of 2-3 houses in the same family. The diesel consumption per generator for 5 hours operation during evening is approximately 2 liters and cost to the families at 60 Baht per day.

The UNICEF generators in Koh Po appear to be working well. The existing distribution system is robust and high quality. Essentially all of it could

readily be used in a future hybrid system. Our team's datalogging revealed that, like Koh Pu, the phases on the Koh Po generator are highly unbalanced (Figure 25).



**Figure 25:** at Koh Po phases were also heavily unbalanced. Only two phases were measured.

### Technical concept for the future PV Hybrid system Koh Po

The proposed hybrid system for Koh Po is similar to Koh Pu. The key differences are:

- Smaller system size (because of lower number of households)
- Somewhat smaller “free” PV array (because fewer households mean fewer SHSs to contribute solar panels)
- Lower initial capital costs by about 1,000,000 baht (\$25,000) because a good electrical distribution system is already in place.

### Key model input assumptions Koh Po

The “optimal system” determined by HOMER depends on the input assumptions. Key assumptions for Koh Po are summarized in the table below. Those assumptions that are different than Koh Pu are italicized.

Variable	Value	Data source	Notes
Interest rate	6%		
Fixed costs	Fixed O&M \$4,500 per year. Fixed capital cost \$ 81,250	Koh Jig experience	(technician salary + power house, transmission line, installation fee)
PV cost	15 kW for \$12,210 25 kW for \$59,820, with linear increase for subsequent PV	PV cost estimated at \$3.9 per watt (Leonics Jun06) + cost includes cost of Sunny Boy inverter (SMA quote).	First 20 kW recycled, and need only grid-intertie inverter.
Solar resource	5.04 kWh/m <sup>2</sup> /day	NREL dataset	
Wind turbine cost	10 kW for \$66,000	Koh Jig installation	Uses Excel BWC S power curve (XLS)
Wind resource	Annual average 3.67 m/s with monthly variations	E for E study – data for Satun Province	Should be considered rough estimate only.
Generator #1	30 kW initial cost \$0.		Existing generator
Generator #2	Sell existing 30 kW for 80,000 baht. Subsequent purchase of 60 kW for \$15,800. Linear interpolation for other sizes	Bangkok IVECO representative estimates	Generator #1 and #2 cannot operate simultaneously
Diesel cost	\$0.86/liter (33 baht/liter)	Village interview	
Converter (inverter)	13.5 kW for \$14,666. Other size costs by linear interpolation	SMA quote for three 4.5 kW “Sunny Island” units	Note – same inverter in Koh Jig costs \$21,050 including tax and shipping
Battery	Hoppecke 12 OPzS. 30 cells cost \$19,452. Other sizes determined by linear interpolation.	SMA quote.	Each cell is 2 volt, 1200 Ah. In actual practice the installation will need batteries in multiples of 30 (because it is a nominal 60 volt system) and therefore may need sizes other than 1200 Ah.

Table 8: Key model input assumptions. Koh Po

PV Array (kW)	XLS (Quantity)	Gen1 (kW)	Gen2 (kW)	Batteries (Quantity)	Converter (kW)
0.000	0	30.00	0.00	0	0.00
15.000	1		30.00	30	8.00
20.000			40.00	40	10.00
25.000			50.00	50	13.50
				60	
				70	

Figure 26: sizes considered for components in Koh Po HOMER model run. XLS refers to the wind turbine.

### 3.4 HOMER Modeling results: optimal system configuration and costs for Koh Po

Figure 27 below shows the results from HOMER modeling for Koh Po.<sup>14</sup> Based on the HOMER modeling, the optimal system for Koh PO is a hybrid solar/diesel system (no wind power), with 15 kW of solar, 120 kWh of batteries, and a 10kW bi-directional inverter. The optimal system has no diesel generator #2. That is, it would be best to sell the second generator and use the money to purchase other hybrid system equipment (though the village might prefer to keep it as a back-up). This “optimal” system uses 20% renewable energy, and the cost of electricity is \$0.484/kWh including depreciation on capital and leveled O&M costs.

	PV (kW)	WLS	Gen1 (kW)	Gen2 (kW)	Batt.	Conv. (kW)	Disp. Stogy	Initial Capital	Total NPC	CDE (\$/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)	Gen2 (hrs)	
	15		30		50	10.0	CC	\$ 114,494	\$ 553,635	0.484	0.20	30,248	3,533		
	15		30	30	40	8.0	CC	\$ 111,624	\$ 553,973	0.485	0.21	31,005	13	3,994	
	15	1	30		50	10.0	CC	\$ 180,494	\$ 613,396	0.537	0.25	28,514	3,383		
	15	1	30	30	50	10.0	CC	\$ 186,291	\$ 614,059	0.537	0.25	28,514	34	3,349	
				30	30	40	8.0	CC	\$ 99,414	\$ 663,063	0.590	0.00	39,921	31	5,150
				30		40	8.0	CC	\$ 93,627	\$ 663,931	0.581	0.00	39,921	5,181	
	20		30	40			CC	\$ 103,433	\$ 710,920	0.622	0.23	43,300	6,929	464	
		1	30	30	40	8.0	CC	\$ 165,414	\$ 717,932	0.628	0.05	37,810	18	4,916	
		1	30		50	10.0	CC	\$ 168,284	\$ 718,388	0.629	0.05	37,039	4,310		
				30	40		CC	\$ 67,418	\$ 765,485	0.670	0.00	49,928	8,251	469	
	20	1	30	40			CC	\$ 169,433	\$ 781,893	0.684	0.26	42,378	6,895	430	
		1	30	40			CC	\$ 133,418	\$ 842,487	0.737	0.05	49,420	8,326	431	

Figure 27: Results of HOMER modeling for Koh Po under base-case assumptions. The first system in the list is the optimal system for the base-case scenario.

The initial capital cost for this system is estimated to be \$114,494 with the battery being the single largest cost (Figure 28). Diesel expenditures over the project’s 20 year lifetime mean that the net present cost is largely dominated by generator fuel costs.

<sup>14</sup> The data file for Koh Po is available at: [www.palangthai.org/docs/KohPo.hmr](http://www.palangthai.org/docs/KohPo.hmr).

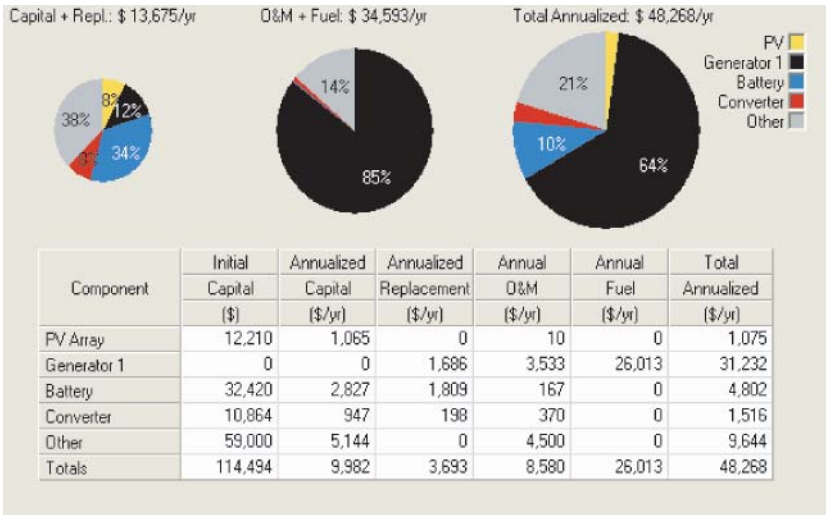


Figure 28: Cost breakdown for the optimized system at Koh Po under base-case assumptions.

### Comparison with diesel only for Koh Po

In order to supply the same electricity 24-hour service using only diesel generators, Figure 27 indicates that optimal “diesel only” system would require a 30 kW and 40 kW generator, with the 30 kW operating 8,291 hours/year and the 40 kW operating the remaining 469 hours/year. In this diesel-only case the cost of energy is \$0.67/kWh. In contrast, the optimal hybrid solution discussed above provides electricity at \$0.484/kWh. The “diesel only” option produces 131 tons of CO<sub>2</sub> per year, whereas the hybrid system produces only 80 tons of CO<sub>2</sub> per year.

### 3.5 Estimated costs, sensitivity analysis for Koh Po

Following Koh Pu study methodology, a sensitivity analysis is included to determine how model outcomes vary with changes in diesel price and load growth.

#### Sensitivity of optimized system design to diesel price – Koh Po

As with the Koh Po calculations, in the base case, diesel price is assumed to be \$0.86 per liter (current prices). In diesel price scenarios, (again) prices are 134%, 163% and 259% respectively, of base-case price. These prices reflect the price in 10 years assuming annual growth of 3%, 5% and 10%, respectively.

Hybrid system equipment capacities, initial capital costs, present value costs, cost of energy, and the renewable energy fraction for optimal hybrid systems diesel price sensitivity scenarios are shown below in Figure 29 and Figure 30.

The results show that in no scenarios are wind turbines a good investment . Instead, higher fuel prices tend to encourage larger solar array sizes, with higher optimal renewable energy fraction (as high as 39%).

Diesel (\$/L)	Wind	Solar	Storage	PV (kW)	XLS	Gen1 (kW)	Gen2 (kW)	Batt. (kW)	Conv. (kW)	Disp. Strgy	Initial Capital	Total NPC	COE (\$/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)
0.860	☑	☑	☑	15		30	50	10.0	CC		\$ 114,494	\$ 953,635	0.484	0.20	30,249	3,533
1.150	☑	☑	☑	25		30	60	13.5	CC		\$ 172,390	\$ 640,195	0.560	0.33	25,344	2,712
1.400	☑	☑	☑	30		30	60	15.0	CC		\$ 197,825	\$ 709,691	0.621	0.39	23,659	2,523
2.230	☑	☑	☑	30		30	60	15.0	CC		\$ 197,825	\$ 952,053	0.833	0.38	24,180	2,650

Figure 29: Fuel price sensitivity results in Koh Po.

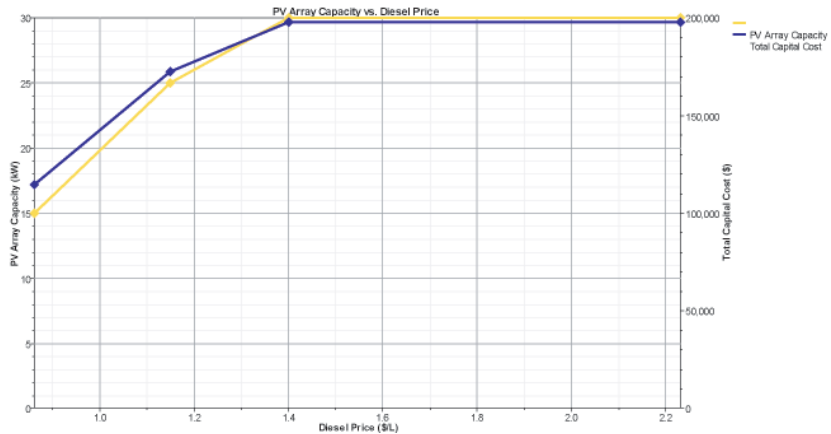
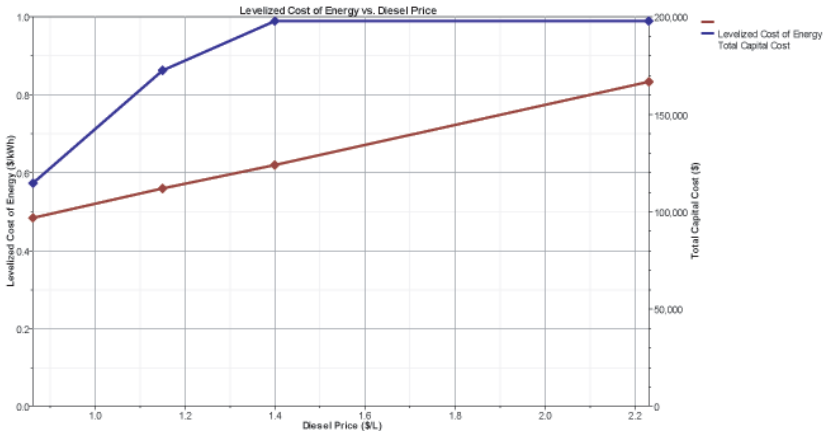


Figure 30: Graph of optimum PV capacity (kW) and total capital cost as a function of diesel price and forecast load in Koh Po. Changes in capital cost closely follow changes in PV array capacity, as PV modules are high-capital cost items.

### Cost of energy sensitivity to diesel price – Koh Po

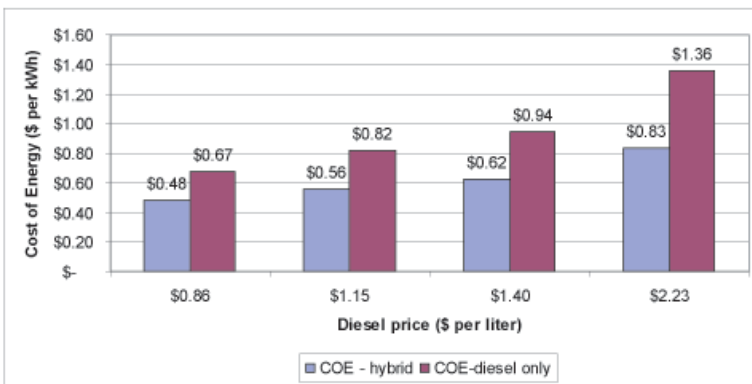
Costs of energy appear to vary nearly linearly with diesel price (Figure 31) – not surprising considering that diesel is the main energy source in the system. Base case cost of energy is \$0.484/kWh if diesel remains at \$0.86/liter. In the highest diesel price scenario (\$2.23/liter) the cost of energy is \$0.833/kWh.

15 This finding may change with better wind data, or lower cost wind turbines.



**Figure 31:** Levelized cost of energy (\$/kWh) and initial capital cost of optimum system (\$) as a function of diesel price.

The overall cost savings from a hybrid system compared with a diesel-only option increases with a mounting diesel price (Figure 32) because hybrid systems make more effective use of diesel fuel, and substitute increasing amounts of solar electricity for diesel-generated electricity in scenarios of high fuel prices.



**Figure 32:** Cost of energy (COE) of optimized hybrid vs. diesel-only under different diesel price scenarios.

### Life cycle cost sensitivity to diesel price – Koh Po

The sensitivity of life-cycle cost (net present cost) to diesel price is shown below in Figure 33, and shows considerable range. Scenarios of high diesel price result in net present cost about \$9,500,000, whereas the lowest end scenario is just over \$550,000.

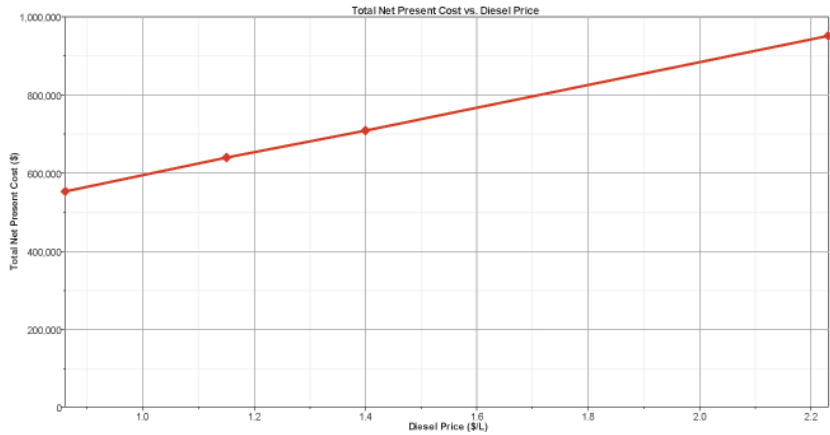


Figure 33: Net present cost as a function of diesel price in Koh Po.

### 3.6 Sensitivity of optimized system design to load forecast – Koh Po

The base case load is forecast to be 273 kWh per day with a peak load of 41 kW. The sensitivity analysis considers an additional high and low scenario of 125% and 75% of base-case forecast. Figure 21 below shows the results of different load forecasts. The factors affected are the PV array capacity and the size of the second generator (generator #2). In low load scenarios, no second generator is required. In the high growth case, a 40 kW generator is necessary.

Pic Load (kWh/d)	PV (kW)	XLS	Gen1 (kW)	Gen2 (kW)	Batt.	Conv. (kW)	Disp. Stgy	Initial Capital	Total NPC	CDE (\$/kWh)	Ren. Frac.	Diesel (L)	Gen1 (hrs)	Gen2 (hrs)
273,000	15		30		50	10.0	CC	\$114,494	\$53,635	0.484	0.20	30,248	3,533	
205,000	15		30		50	10.0	CC	\$114,494	\$49,348	0.524	0.26	21,524	2,468	
341,000	20		30	40	50	10.0	CC	\$146,717	\$63,205	0.458	0.22	36,508	3,595	461

Figure 34: Load forecast sensitivity results in Koh Po.

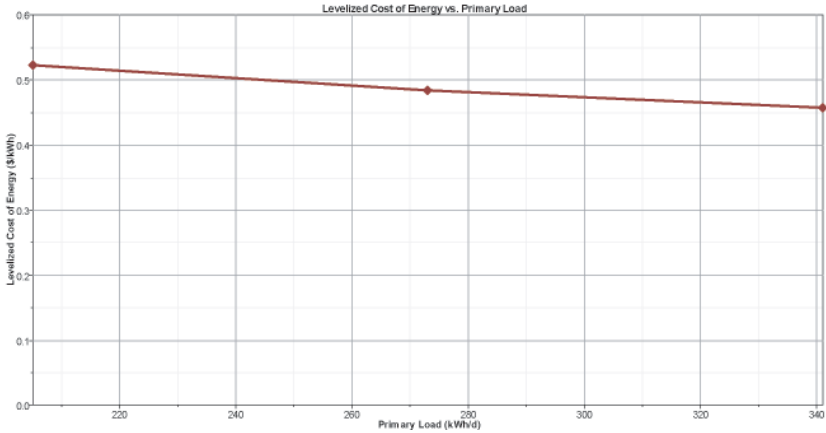


Figure 35: Levelized cost of energy as a function of forecast load in Koh Po.

As with Koh Pu, in Koh Po levelized cost of energy is nearly constant for all load growth scenarios, declining slightly in high growth scenarios because of more optimum loading of generators.

Under scenarios of low, medium, and high load growth the “hybrid option” remains more cost-effective (lower levelized cost of energy) than the diesel-only option (Figure 23).

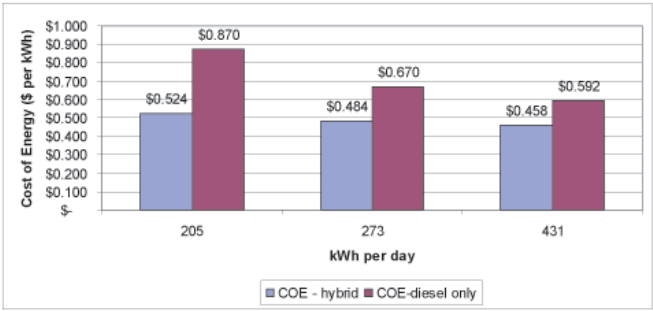


Figure 36: Cost of Energy (COE) of optimized hybrid vs. diesel-only under different load growth scenarios. (Koh Po)

### 3.7 Koh Po Summary and recommendations

As with the Koh Pu case, HOMER modeling results indicate that Koh Po’s electricity needs could be met at considerable overall cost savings with a hybrid (renewable energy/diesel) system compared with existing arrangements (separate diesel generator plus solar home systems).

At existing diesel prices and in a “base case” load scenario the optimal system for Koh Po is a hybrid solar/diesel system (no wind power), with 15 kW of solar, 120 kWh of batteries, and a 10kW bi-directional inverter. The optimal system has no diesel generator #2. This “optimal” system uses 20% renewable energy, and the cost of electricity is \$0.504/kWh including depreciation on capital and levelized O&M costs.

Though the optimum system configuration changes under different load growth and diesel price assumptions, the hybrid system remains more cost-effective than the existing arrangements (diesel-only), under all scenarios considered.

The suggested step-by-step approach for Koh Po is essentially the same as is described above for Koh Pu. Because of economies of scale in transportation, effort and equipment, it may make sense to work with both communities more or less simultaneously.

The section following describes possible funding options.

## 4. Funding options for both Koh Pu and Koh Po

Assuming that base-case assumptions are correct, Koh Pu requires about \$145,000, and Koh Po requires about \$114,000 in capital costs. Several sources of funding are possible: debt or equity financing, local infrastructure funds, Thai grants, and international grants. An optimal solution may involve a combination of sources. This discussion starts with the villagers’ willingness to pay.

### Willingness to pay

Currently, the villagers pay prices for (intermittent) electricity that is close to the electricity cost from an optimized hybrid system (Table 9). A big difference, though, is that the prices currently paid by villagers only covers diesel costs, and is not enough to set aside funds for equipment replacement whereas efficiencies enabled through a hybrid system allow this same amount of money to cover capital and replacement costs in the hybrid case. Another big difference is that currently electricity is only available a few hours a day, making the use of refrigerators impossible. A hybrid system would provide a 24-hour service. However, villagers do not currently pay for electricity from their solar home systems, and would be losing this “free” source of electricity if a hybrid system used these solar panels.

	Koh Pu	Koh Po
Current electricity price (intermittent, <u>not including</u> equipment depreciation costs)	\$0.650	\$0.390
Optimized hybrid electricity cost (24-hour, <u>including</u> equipment depreciation)	\$0.422	\$0.484
Perceived savings from hybrid	\$0.228	- \$0.09

**Table 9:** comparison of current electricity prices to projected hybrid system electricity costs. The low tariff at Koh Po reflects extremely low salary (1,000 baht/month) paid to the system operator, and is probably not sustainable.

All in all, the figures in Table 9 suggest that a hybrid system could pay for (or come close to paying for) itself.

### Debt or equity financing

Debt (loans) or equity (sale of stock) financing can help overcome the hurdle of high capital costs without a dependency on grants. Also, the presence of a substantial debt or equity portion in the project can give grant makers more confidence that the grants they are providing are leveraged to provide maximum benefit.

Several finance corporations have explicit mandates to fund clean energy, and can do so at attractive rates. One such group is “E & Co.”, which has an office in Bangkok.<sup>16</sup> E & Co. has about \$8,000,000 currently available to lend in Asia, and is willing to receive lower than market rates for community projects that have high social benefit. The minimum amount of an investment is around \$50,000. E & Co might be willing to helping the island ESCOs to develop good business plans. Another potential group is the Renewable Energy and Energy Efficiency Partnership (REEEP) which could possibly help put together a package of funds.

### Grants

Grants can help reduce costs to villagers and lower risks associated with fairly new applications of technology. A \$50,000 grant to each community would have the following impact on the levelized cost of energy, net present costs, and on initial capital costs:

	Koh Pu	Koh Po
Cost of energy (no grant)	\$0.429	\$0.484
Cost of energy (\$50K grant)	\$0.400	\$0.441
Net Present Cost (no grant)	\$736,549	\$553,635
Net Present Cost (\$50K grant)	\$686,549	\$503,635
Initial Capital (no grant)	\$116,129	\$114,494
Initial Capital (\$50K grant)	\$66,129	\$64,494

**Table 10:** A \$50K grant has a substantial impact on the initial capital cost, but a rather limited effect on the cost of energy because so much of the cost is (expensive) diesel fuel.

### Local infrastructure funds

The local government (Tambol administration) has funds allocated for infrastructure development. In Koh Jig these funds were used to help purchase wind turbines for the hybrid system. In Koh Po they have been used to help pay for the distribution system that is currently connected to the diesel generators. On Koh Pu the funds were used to build roads and a good pier.

### Thai Grants

The Energy Conservation Fund (ENCON Fund) jointly managed by the Energy policy and planning office (EPPO) and the Department of Alternative Energy Development and Efficacy (DEDE) provided the bulk of funds for the installation of the system at Koh Jig, due to a successful grant application submitted by Ajarn Tawatchai (one of the collaborators on this project). Grants application must be written in Thai.

### International Grants

International grant making organizations may be interested in this project for several reasons:

<sup>16</sup> E & Co. contact: Asia Regional Manager Jeffery Dickinson jeff@energyhouse.com.

- Environmental benefits (e.g. global greenhouse gas reductions)
- Community development benefits, especially in post-tsunami context
- Supporting innovative applications for renewable energy technologies

Possible grant-making entities include the UNDP/GEF small grants program, and private foundations such as the Blue Moon Fund or the WISIONSs fund. There may also be tsunami-specific funding opportunities.

### **UNDP/GEF Small Grants Programme**

The GEF Small Grants Programme (GEF/SGP) was launched in 1992 by UNDP. The GEF/SGP provides grants of up to US\$50,000 and other support to community-based groups (CBOs) and non-governmental organizations (NGOs) for activities that address local problems related to the GEF areas of concern.

The principle objectives of the Small Grants Programme are to:

- Demonstrate community-level strategies and technologies that could reduce threats to the global environment if they are replicated over time
- Draw lessons from community-level experience, and support the spread of successful community-level strategies and innovations among CBOs and NGOs, host governments, development aid agencies, the GEF, and others working on a larger scale;
- Build partnerships and networks of local stakeholders to support and strengthen community, CBO, and NGO capacity to address environmental problems and promote sustainable development. In the area of climate change, activities must either demonstrate the removal of local barriers to energy conservation and energy efficiency, or promote the adoption of renewable energy. GEF/SGP contact in Thailand: [poonsin.sreesangkom@undp.org](mailto:poonsin.sreesangkom@undp.org)

### **Blue Moon Fund**

The Blue Moon Fund makes grants to nonprofit organizations that have developed innovative, holistic approaches to improving the human quality of life in harmony with the natural world. The “rethinking energy and consumption” initiative is aimed at developing environmentally-friendly, efficient, and economically competitive transportation and energy choices worldwide. The driver behind this program is climate change, which is on course to radically alter both human quality of life and the natural environment. Reversing this course will require financial and political commitments to technologies that reduce emissions and offer alternatives to fossil-fuel based economies. More info: [www.bluemoonfund.org](http://www.bluemoonfund.org)

## WISIONS

The Wuppertal Institute for Climate, Environment and Energy runs the WISIONS Sustainable Energy Project Support (SEPS) and provides support to rural renewable energy projects. In describing the program, the WISIONS website says, "Realistic visions and concepts of effective projects for sustainable energy exist, but much needed implementation sometimes fails. SEPS has the key objective of identifying those projects with the real potential to be of strategic importance in renewable and efficient use of energy. By providing technical and other forms of support, SEPS seeks to overcome the barriers and will help clean and efficient energy become commonplace. Projects supported must be innovative, sustainable and can be replicated in other parts of the world.

They have to be in a state ready for implementation and a well-developed implementation strategy must exist. Support criteria include: Technical viability of the project, economic feasibility, and it must provide local and global environmental benefits."

One project already supported by the foundation was the "Solar Energy Technologies for livelihood recovery of tsunami affected fishermen communities" which provided support to IT Power India (ITPI) to demonstrate the suitability of solar energy based technologies and a community owned business model to recover and enhance livelihood of fishermen communities in a region affected by the Tsunami in 2004. See: <http://www.wisions.net/pages/SEPS.htm#Anchor-49575>

## 5. Maintenance requirements and training

Based on the experiences around the world, local maintenance and management capacity is absolutely essential for stand-alone rural electrification projects. Koh Pu and Koh Po are no exception. In addition, the knowledge by the local management and technicians about how to save energy can have a significant positive impact in lowering energy costs. Fortunately, experience has already been gathered as a result of training villagers to operate and maintain the hybrid system at Koh Jig.

Technician skill requirements:

- Electrical troubleshooting
- Energy conservation
- Diesel maintenance (oil changes, etc.)
- System theory & operation

Manager

- Basic understanding of how the system works
- Energy conservation
- Cash flow accounting
- Leadership

Accountant

- Basic understanding of how the system works
- Energy conservation
- Cash flow accounting

## 6. Koh Jig PV – Hybrid system: an example for Koh Pu and Koh Po, with lessons learnt

### 6.1 Koh Jig system overview

The PV/Wind/diesel hybrid system on Koh Jig was funded by the Thai government and intended as a pilot project on Mini-Grid for Rural Electrification from Hybrid Systems. The project was studied and implemented by King Mongkut University of Technology, Thonburi (KMUTT). Although the concept of such a system is not a new idea, similar hybrid systems were installed in other countries and some reportedly failed primarily due to inadequate training, under stocked spare parts and other non-technical problems that lead to frequent and long interruption of power service and reliability of the system. Koh Jig's hybrid renewable energy system was implemented using a step-by-step approach incorporated with the energy service company (ESCO) concept to ensure a reliable and sustainable system operation. The system started its operation in October 2004. Since then, it has been providing 24-hour reliable electricity to the island's fisherman community of 100 households, a school and a temple. While the community centers such as the school and temple have free access to the electricity, the households pay their charges with prepaid "smart cards" that can be refilled at any level they can afford. The hybrid system electricity tariff is currently about 20 Baht/kWh.

Koh Jig hybrid system implementation was divided into 5 activities.

1. Community consultation
2. Organizational structure for ESCO
3. Engineering
4. Training
5. Evaluation and assessment

During the community consultation process, the community discussed the shortcomings of their existing electricity supply arrangements, and the idea of the hybrid system was explained and proposed as a project. The community also discussed administrative models and concluded that forming a community energy service company (ESCO) would be most appropriate. Subsequently, the administrative details of the ESCO were worked out in consultation with the community (Figure 39). Engineers from KMUTT then developed a system design, and conducted training classes for the ESCO staff and governance board. Training classes included technical training for community technicians, as well as training in accounting and project management. Finally, the project is undergoing on-going evaluation and assessment.

The hybrid power system was designed to have power from three sources: solar photovoltaic, wind turbine, and diesel generator. A battery bank provides for energy storage. A load forecast for Koh Jig estimated that the energy demand would be 265 kWh per day with a peak demand at 37.5 kW. However, the project cost was under-estimated and there was not enough of a budget for the wind turbine. The system operated with PV and a generator for the past 18 months until funding became available for the wind turbine, which was installed in May 2006.

Power sources	Power	Energy production	Energy fraction
PV	7.5 kW	9,644 kWh/year	7%
Wind turbine	10 kW	11,367 kWh/year	8.4%
Diesel generator	65 kW	115,080 kWh/year	84.6%
Total	82.5 kW	136,091 kWh/year	100%

Table 11: Designed power supply for Koh Jig hybrid system.

The renewable energy fraction of the original design hybrid system is 15% which would reduce diesel consumption at 49,641 liters/year. Although power from the renewable source does not significantly contribute to the supply, using one large generator placed far from the village center has improved the environmental impact in oil spills and loud noise from the village’s old power supply system of using 52 sets of small individual generators.

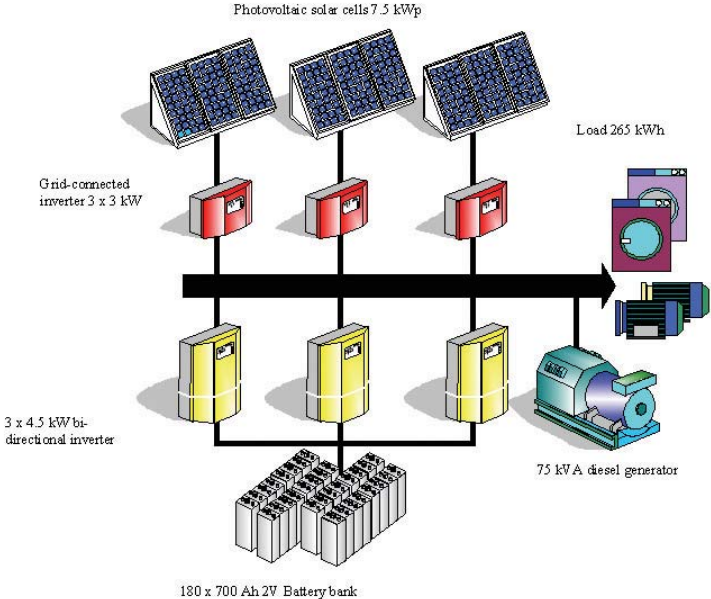
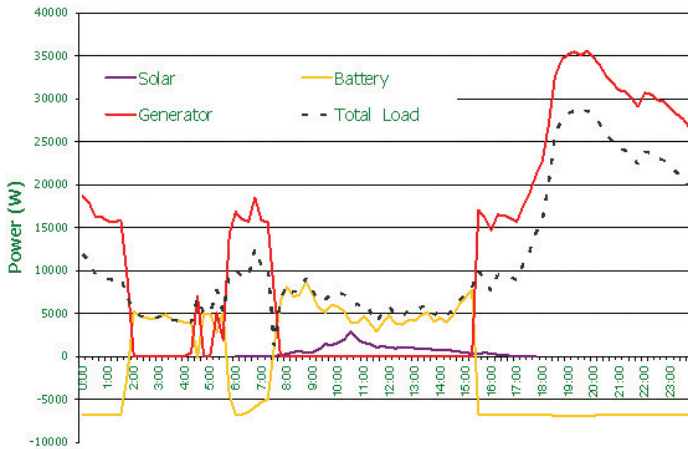


Figure 37: Koh Jig hybrid system configuration



**Figure 38:** Koh Jig hybrid system power balance on 16 January 2005 representing a typical daily load.

The generator is scheduled to turn on at peak demand during the morning and evening hours. In the day, village power is supplied by solar energy and a battery bank. The batteries are charged primarily by the generator to ensure they have the optimal charge and discharge cycling. When electricity load demand is less than the power generated from the solar photovoltaic, the excess power is rerouted to charge the battery bank. Figure 38 shows the power balance between supply and demand on a typical daily load. The peak demand is generally during the hours of 5.30AM-8.00AM when the villagers prepare their meals using high power consumption rice cookers and peaks again in the late afternoon for dinner preparation, rising to the highest level of the day during 18.00PM-22.00PM, show times of the local favorite programs on TV.

Data from the digital datalogger on 16 January 2005 shows that energy balance during the day is

PV	8.0 kWh
Generator	294.0 kWh
Battery	23.8 kWh (discharge 56.9 kWh and charge 80.7 kWh)
Load	274.6 kWh

**Table 12:** Digital Datalogger data.

Total energy supply from PV, generator and battery was 278.2 kWh while the energy demand was 274.6 kWh. Energy difference between the two data was losses in the system and partially consumed in the control equipment. There

is also a loss in the battery bank as typical efficiency of the battery is 80%. However, data of the battery charge and discharge shown above can not represent the battery efficiency because it may not be fully discharged. The battery discharge depends on energy demand and solar radiation for the day while battery charging depends on the state of the charge from the day before.

### 6.2 Koh Jig management and operation

A crucial issue to the sustainability of the hybrid system is the management and operation. An Energy Service Company (ESCO) was set up with consensus of the community. It reports to the Energy Committee which is elected from the villages and is up for reelection every four years. The committee oversees the equipment procurement, financial and accounting of the ESCO. It also decides on the electricity tariff changes in response to fuel costs. The collected money is spent on fuel payments, salary of the ESCO 4 full-time staffs, and the rest is saved for the future maintenance of the hybrid system such as replacement of batteries and other equipment. The organizational structure for the management of the village hybrid system is shown in Figure 39.

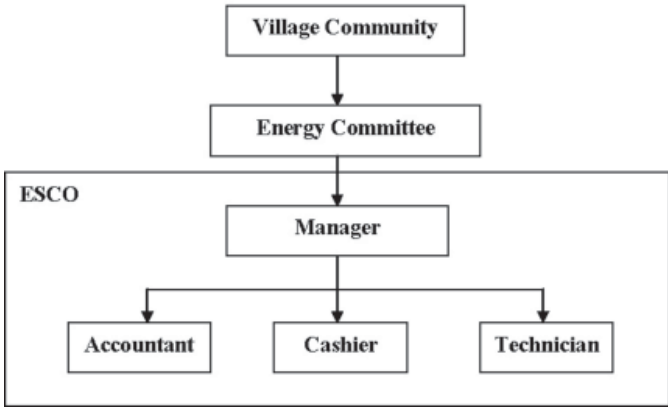


Figure 39: Organizational structure of Koh Jig Energy Service Company (ESCO).

Koh Jig uses prepaid kWh meters for the collection of electric charges. The smart cards contain identification of the owner and the money available in the card. When the user slips the card into the socket on the meter the card is programmed to read data only from the card that has a matched identification. The money in the card will be converted to kWh units available on the meter and the money in the card will read zero until it is refilled at the ESCO office which is open 6 days per week. The card can be

refilled at any amount of money the customers can afford. The ESCO office has a computer to record all data including customers' identification and the amount of money paid with date and time. At the end of the month, the accountant can easily add up all the transactions for the total amount which should match with the money the cashier has collected over the month. The community understands and accepts the concept of using smart cards very well as it is similar to using prepaid phone cards. It requires no special training for customers and only some basic computer training for the cashier. The smart card can be programmable so that it gives flexibility to changes of electricity tariffs. Although, smart kWh meters cost more than normal meters, it eliminates the risk of non-payment and reduces the time consuming monthly billing process for reading meters, preparing the bills and collecting money.

The smart meters used on Koh Jig were imported from China as there is none locally made. The cost of smart meters for 100 households was approximately 1,755 USD (excluding tax and shipping). The price breakdown is shown below.

Item	Unit price	QTY	Total
1. Smart kWh meter + 1 smart card/meter	\$16	100	1,600
2. Card reader and software	\$75	1	75
3. Extra smart card	\$0.8	100	80
			1,755

**Table 13:** The Cost of smart meters.

The cost of the hybrid system on Koh Jig was approximately at \$201,000 which was funded by the Thai government as a demonstration project. Customers pay for meters and smart cards. Koh Jig capital cost is higher than Koh Pu (\$116,129) and Koh Po (\$81,494) as the island did not have available PV and a diesel generator in the existing system. The existing distribution line on Koh Po also has a lower initial investment for the island.

### 6.3 Koh Jig: lessons learnt

1. The prepaid smart meters have eliminated the risk of non-payment that can happen in a traditional billing arrangement. The meters seem to work well technically and the community has enthusiastically accepted them. The ESCO staff also has had no problems managing the technology. By installing the meter in prominent location, and due to the high tariffs charged, they appear to have a strong effect on energy conservation. People know that cooking a pot of rice will take about 0.5 units and cost 7 baht. An hour of TV will consume about 0.1 units and cost about 1.5 baht.
2. The Koh Jig success case in the community owned and operated hybrid system owes largely to the careful community consultation process during the early phase of the project through several workshops. The community understands the concept of the hybrid system and knows the risks that could jeopardize the system reliability. The banning of high power consumption equipment such as Air conditioning on the island was made in consensus with the community.
3. Although the technician is well-trained and capable of the daily system operation and maintenance, there could be occasions when imported equipment such as inverters failed either by themselves or through other means. The Koh Jig hybrid system is still being closely supervised by an engineer at KMUTT who put the system in place and was able to handle the process of claiming guarantees and the replacement of faulty equipment with the manufacturer in Germany. It is therefore recommended that hybrid systems on other island such as Koh Po and Koh Pu should have ties to academic institutions or NGO support when the systems need to be repaired.

## **7. Initial discussions with Koh Pu and Koh Po Communities (added by Tsunami Aid Watch)**

After initial discussions with TAW staff, the communities of Koh Pu and Koh Po stated their intentions to:

- Apply a similar management and operation model as the one successfully implemented in Koh Jig.
- Select members of an energy committee from respected members of their communities (the length of service to be decided by each community).
- Establish a Renewable Energy Company (ESCO in Koh Jig) and select the management team, consisting of a manager, an accountant, one office staff, a treasurer plus two technicians (slightly different from the Koh Jig ESCO structure).
- Participate jointly in the decision making process for the Renewable Energy project. Sufficient information and knowledge should be fed back from the Energy Committee and the Energy Company to the community, so that every community member can make informed decisions on the issue at hand.
- Return possible future profits (e.g. from tourism businesses that might be established) to the community by contributing to a community development fund.

The communities will need external assistance in order to gain the knowledge of how to operate the hybrid energy system. The communities requested that some of their members should be trained to study the management structure of the system in place at Koh Jig. External experts with a full understanding of the technical issues will be needed to ensure that problems on that level will be solved and don't lead to system failure.

## 8. Attachment

### 8.1 Synchronization

Synchronous generators can only be electrically connected together when their frequencies and phases are equal. There are two possibilities: (a) automatic synchronization; (b) manual synchronization.

Automatic synchronization involves installation of a synchronizer. A synchronization package recommended by the IVECO agent in Thailand would be estimated to cost around \$7,000.

Synchronizers manufactured by Beckwith Engineering Inc. (<http://www.beckwithelectric.com/synchro/m0193/m0193b.htm>) or Governor Control System, Inc. (Woodward Digital Speed Matching Synchronizer – see <http://www.govconsys.com/dsm.htm>) could possibly be made to work, but it may require modification to the generators so that the digital signal from the synchronizers can control the frequency of the generator. The price of the Beckwith M-0193 is \$3,484 US, FOB Florida, USA.

A far simpler option, appropriate for smaller scale generators (according to the Beckwith sales representative) is manual synchronization using a synchroscope.<sup>17</sup> When the synchroscope indicates that frequency and phase are matched (within 10 degrees is generally suitable for small generators) then the operator closes the breaker connecting the two machines. A synchroscope costs around US \$230.<sup>18</sup>

While this option is considerably cheaper than an automatic synchronizer, it does require that the generator operator be properly trained to close the switch only when the synchronizer indicates that it is safe to do so. Failure to do so could cause significant damage to the generator. Because several generator starts are likely per day, this presents a high – and perhaps unacceptable – chance of accident/failure.

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<sup>17</sup> Operation of a synchroscope is described at: <http://en.wikipedia.org/wiki/Synchroscope>.

<sup>18</sup> <http://weschler.enterprisemerchant.com/Product.aspx?ProductID=218&CategoryID=1936>

## 8.2 Koh Pu and Koh Po community background

### 8.2.1 Koh Pu Community: M.2 Sri Boya sub district, Nua Klong district, Krabi

#### Background/ History

Bahn Koh Pu community can be traced back in time for more than 200 years based on artifacts found in their ancestor's grave yards. The artifacts discovered are weapons of Malaysian warriors who migrated from a nearby province; the first inhabitants were composed of five families who began settlements in the Bahn Klong Kla area. Due to the rich soil and plentiful natural resources these early settlers were joined by their relatives then other migrants from Onk Kom island and Kalatan and Malaka in Malaysia, establishing a thriving community. The name Koh Pu comes from Malaysian words 'Pulau Katum' which mean 'The Island of Crabs' due to the large number of them found in the area.

#### General information

Bahn Koh Pu is one of the three main villages on this island, with a total area of 15,000 Rai, connected by both road and boat with Bahn Jum and Bahn Ting Rai.

In the north, when the tide is low, sea weed and wing shell can be collected to increase their income and to the south are Koh Pu's fields of rubber trees with a connecting area to Bahn Ting Rai. Further east is Tu Lang island, also rich in natural resources.



#### Social and Cultural structure

Bahn Koh Pu is composed of 150 households with a total population of 1,160, 95% of the people are Moslem and the rest Buddhist. Lifestyles in the community are basic, with men as the main labour force in fishing, agriculture and the repair of houses and boats, with women taking care of children and the household.

## **Economy**

All members of the village have more than one occupation. For example they may own rubber trees and also go fishing to earn more income. There are 44 households that own rubber trees, 44 that work as fishermen and another 40 work as employees.

Public Utilities and assets in the village:

- Kindergarten/ Child care centre
- Primary school (up to grade 6)
- Public utility building
- Public payphone
- Sports/ Playground
- 12 Community wells
- 2 Electric Solar Cells
- 2 Mosques
- Port/ Dock
- 1 Natural fresh water source
- 1 Weaving factory

Bahn Koh Pu Savings bank is a special community organization

## **Natural resources**

Bahn Koh Pu is rich in natural resources; this comprises a large area of sea (700-1,000 Rai) that includes a sea turtle feeding area, dugong breeding ground, wing shell collecting grounds, crab, and all kinds of fish. Forest (approximately 1,000-1,500 Rai) which is the habitat for monkeys and other animals and adjacent to the hills to the west of the village provides fresh water and wood for housing and fishing boats. A plateau on a hilltop will be developed into a tourist attraction.

### **8.2.2 Koh Po Community: Koh Lanta Yai sub-district, Koh Lanta district, Krabi**

#### **Background/ History**

The first migrants to arrive on the island were the sea people of Urak Lawoi. They eventually moved away to make a settlement at Bahn Hua Laem at present day Aow Klang Bay. The island was originally called 'Dur Po' a name that originally meant 'rope used in a fishing boat' as the island was rich in kenaf which were used to make ropes. The Urak Lawoi also named the five other bays which are still inhabited today; Lo La Mard, Pra Aok, Nai Bann, Ta Kung and Lo Biba.

Local legend has it that later on a migrant from Pattalung called Khun Samutra came to the island with his family. Whilst his children lived on Koh Po, Khun Samutra went to live on Koh Hai island, traveling to and from Koh Hai to plant coconuts on Koh Po.

In time a man named Toh Nuan came from the mainland to ask Khun Samutra for some land. After he was rejected he contacted a group of bandits to help him invade Koh Po but was repelled by Khun Samutra's grand children. Later, all the bandits were captured and executed.

Lo La Mard bay was the first location for Chinese migrants to settle in this area, most of Khun Samutra's descendants married and moved away whilst many other migrants arrived to begin a new life on Koh Po.

### **General information**

Bahn Koh Po is composed of 87 households (104 including extensions to existing households) with a population of 467.

Total area of the Koh Po is 1,400 Rai surrounded by sea with high mountains running down the spine of the island. Soils are a mixture of earth and sand and natural fresh water can be obtained from wells dug no deeper than 5 meters.

#### Connecting area

North	Koh Nui island
South	Koh Kluong Island
East	Trung
West	Koh Lanta Yai island

### **Economy**

95% of the population are fishermen while the rest work in rubber plantations, leaving only a small fraction of families working as employees in Trung. The minimum monthly income from fishing is approximately 5,000 Baht with the catch being sold at Sri Raya and Bo Muong piers. Dried fish is the only household industrial enterprise established on the island which is still ongoing.

### **Roads**

In 1999 the community received a budget for road construction for the 3km from Nai Ban bay to Pra Aok bay as well as an annual budget from the sub-district office to build a 2 meter wide concrete road at 200 meters a year connecting the bays.

### **Environment**

Most of the soil is sandy, only suitable for rubber and coconut trees. While 30% is owned by islanders, the rest, 70% has been sold to developers. The value of beach property has increased since the Tsunami from 300,000 baht per Rai to 700,000 Baht per Rai.

**Water supplies**

The main fresh water supplies come from an underground water source, which is pumped up and stored in water tanks at two locations at Nai Ban and Pa Aok bays. These underground water sources have been in use for some time now and are insufficient for everyone in the dry season (March-May). Some families manage to store rain water for use during this period of water shortage.

**Social & Cultural structure**

Nearly the whole population is Moslem, only ten families are Buddhist and they have separate spiritual practices. On two days a year (Areyo day) they come together for joint celebrations ( January and November).

**School**

The school was built in 1974; there are three teachers responsible for 60 students, providing education from kindergarten level to grade 6.

## **9. Forthcoming publications under Tsunami Aid Watch**

### **Short term research projects**

1. Social and cultural effects on Tsunami impacted populations receiving aid from religious organizations.
2. Land problems after the Tsunami.
3. The changing ways of life in Andaman's coastline communities.
4. Operating structure of Save Andaman Network (SAN), a case study on rebuilding houses and rehabilitating the communities.
5. Operating structure of the Save Andaman Network (SAN), a case study of boat repair and community shipyards.
6. Morgan culture and its origins
7. Tsunami early warning system: Myth and Reality
8. Changed environments: Permanent effects of the Tsunami on communal ecology

### **Long term research projects**

1. Data collection regarding land problems and solutions for Tsunami impacted areas.
2. Morgan (Sea-gypsies) ways of life and the history of Morgan land use.

### **Other projects**

1. Tsunami Seal, a suggestion for a fair and suitable standard for the disaster affected communities regarding hotel and resort businesses in the Tsunami affected area; also to increase tourists' awareness of hotel business developments that do not have negative impacts on the local surrounding communities.

### **Previously published**

1. TSUNAMI. A study on disaster response in Sri Lanka, with a contribution on the situation in Thailand by Karl Segschneider, Director of the TAW project, and Walaitat Worakul, published by Heinrich Böll Foundation, Brot für die Welt and medico international, July 2006.
2. Sustainable Community Owned Professional Eco-Charters (SCOPE-Charters). An Alternative Ownership Model in Eco-Tourism, ISBN 978 974 88189 7 9. Edited by TAW, a project of the Heinrich Böll Foundation, Southeast Asia Regional Office, Chiang Mai, December 2006.

**Project period:** November 2005 – January 2008