A Hybrid Renewable Energy Based Rural Electrification Project for Eastern Indonesia

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INTRODUCTION

Through a large scale rural electrification project it is planned to supply 66 villages in Eastern Indonesia with renewable energy based hybrid electricity systems which have peak kW power delivery capacities from 20kW up to 50kW. The anticipated respective energy outputs of these systems will be in the range of 50kWh up to 150kWh per day. The hybrid power system is a combination of conventional and new renewable energy sources.

Indonesia, the fourth most populous nation in the world, is an archipelagic country with over 13,000 islands and a census population in 1990 of 182.6 million. This number now exceeds 200 million people. The country is comprised of 27 provinces that consist of 63,000 villages. In the last decade (1980-1990) the national population grew at 2.13% per year in average. At 1990 over 77% of the national population was living in rural areas and 23% in urban areas.

Major infrastructure developments needed in Indonesia include transportation, communications, education, health, clean water, sewerage and energy supplies. Energy supply is especially important within the economic development question in that it is also a basic resource needed for most of the above infrastructure items. Beyond this the rapid growth in the need for additional electricity capacity imposes significant impacts, not just upon Indonesia but also in a global sense with increasing international concern over the greenhouse issues.

Advanced Energy Systems Ltd (AES) has been involved in various project activities in Indonesia and elsewhere internationally since 1988 at which time AES was subcontracted by the Western Australian Government to undertake a study of the potential for new energy technologies in South East Asia. In August 1994 representatives from the Indonesian Agency for Assessment and Application of Technology (BPPT) visited Australia and this was followed by an invitation for AES to attend a UNESCO round table conference held in Jakarta early in 1995. A number of visits have been made to Eastern Indonesia whereby a great deal of data has been compiled in regard to regional requirements, demographics and cultural issues.

DEFINITION OF THE DEVELOPMENT PROJECT

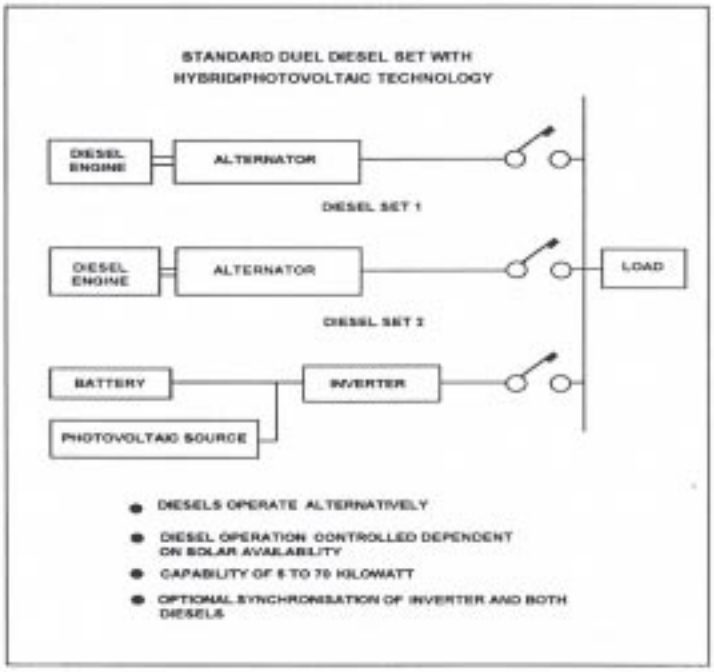
Each village included in the project will have a localised distribution network installed and connected to the centralised renewable hybrid power station. The renewable hybrid system (as depicted in the block diagram below) will comprise various components that will be integrated into the total system. It is planned that two systems will be utilised; System A which will serve villages from 75 to 125 households and System B which will serve villages with 150 to 250 households.

The components include the following:

- Renewable component such as photovoltaic modules or small wind turbines
- Storage devices such as lead acid batteries
- Power electronic conversion unit or inverter
- System control module with inbuilt remote monitoring and control capability
- Diesel engines
- Small power station enclosure
- Electrical distribution system

- Household wiring kit
- Prepayment meter system

The hybrid design approach is considered to be technically superior to the solar panel home lighting approach as the hybrid system can deliver much greater amounts of energy at lower cost per kWh while also meeting industry, education and health needs in the process. The hybrid system is expandable and very flexible with both the service and the cost being able to be spread over the whole village. This ensures equity in cost sharing and access to the service.



Hybrid System Overview

An Integrated Electricity Plan (IEP) will be implemented at the cooperative level (KUD) with revenue being collected through the rural banks. The local village KUD or another authorised KUD will manage designated locations at which electricity will be prepaid and will also be involved in future demand and supply side management options. It is intended that this will incorporate metering capable of storing a credit payment system.

The network and hybrid power station will have communication mechanisms installed which will enable remote monitoring and local service networks to ensure that the village's IEP plan is maintained. The initial support, transfer of ownership and eventual full local support of the system will be a central part of the projects objectives.

SECTORAL DEVELOPMENTS RELEVANT TO THE PROJECT

The application of renewable energy and solar electric photovoltaic (PV) systems in Indonesia is directed especially towards rural areas, remote islands or areas where an electricity grid is not available. During the 1990s the utilisation of PV systems has been growing and the total capacity of PV systems installed by the end of 1993 was estimated to approach 2MWp. This included more than 16,000 solar home system (SHS) units, approximately 370 units solar PV for small refrigerators for rural health clinics, approximately 110 units of PV water pumping systems, 22 small scale television repeater stations, 120 public television receivers and 50 telecommunications repeaters.

It is relevant to understand the institutional environment in Indonesia. As the power utility (PLN) undergoes corporatisation and possibly fully privatisation in the near future it will then be likely that many areas of remote Indonesia will not be serviced with electricity. Such rural energy services are typically loss making for a mainstream utility and not commercially attractive for any utility. Ministerial decrees have been issued in regard to the conditions relating to private power providers.

This project lays the basis for possible private sector operation of renewable energy systems in the areas not currently or likely to be serviced by PLN.

Four PV hybrid pilot systems have been installed to study the potential of optimising the energy resources available. As a continuing effort in rural area electrification an installation of 50MWp total capacity of SHS (one million households) is to be implemented during the FYDP VI (1994/95-1999/2000). These programs have placed Indonesia in the forefront of international developments of renewable energy systems.

RECIPIENT GOVERNMENT PRIORITY

In order to promote the social and economic development of rural Indonesia the Government has established rural development and electrification as an issue at the highest political levels. Unfortunately the fragmented geography of Indonesia creates special problems for rural electrification not faced by most countries. Local grid projects using generation from wind, photovoltaic, hybrid or geothermal sources are in the pilot or planning stages and individual household photovoltaic systems have been installed in pilot villages.

The Indonesian Government places this project high in relevance to national, regional and provincial strategies. The priority for the development of new and sustainable infrastructure in Eastern Indonesia has been well documented. President Habibie outlined the case most succinctly at the 1995 UNESCO round table conference in Jakarta when he said:

"Solar energy utilisation in Indonesia will get an attention. It is used to solve the micro economic problem of ratio of GDP growth toward population growth in remote villages. 61.3% of Indonesians do not enjoy electricity. How can you ever expect small industries to be very efficient and productive if they do not have electricity."

Solar photovoltaic generation and its application in utility grade hybrid systems is of particular interest because of its flexibility, low environmental impact and greater freedom from fuel requirements. In the last five years the Government of Indonesia has participated in projects resulting in the installation of over 1MWp of photovoltaic capacity in rural areas of the country.

AUSTRALIAN DEVELOPMENT ASSISTANCE OBJECTIVES

Australia's assistance program aims to address more effectively Indonesia's emerging development priorities.

Over five years, commencing 1993/94, the documented AusAID policy has been:

- Continue to focus mainly on projects in Eastern Indonesia with an emphasis on poverty alleviation, infrastructure development and environment management
- Maintain and consolidate the sectoral focus on human resource development
- Contribute to poverty alleviation through family planning and maternal and child health activities and support for local community development activities
- Promote closer economic and commercial linkages and relations between the Australian and Indonesian private sectors and productive enterprises through activities which support Indonesia's development goals

In accordance with Indonesia's priorities Australia's program seeks to:

1 Contribute to Indonesia's development through practical cooperation in areas of mutual interest, particularly in sectors where Australia offers a high degree of relevant expertise

2 Promote bilateral economic links which are consistent with sustainable development and conducive to long term partnership

Poverty alleviation has become a major focus of Australia's development cooperation program. Australia's technical assistance projects in Eastern Indonesia focus on agricultural development and the provision of infrastructure. The environment and ecologically sustainable development and the involvement of women are key issues which touch on all of Australia's development cooperation objectives. The success or otherwise of many of Australia's development cooperation activities in Indonesia depends on community commitment and involvement.

PROJECT DEVELOPMENT ISSUES

Based on the experience gained to date from developing renewable energy in rural areas there are several major issues, particularly appropriateness of technology, affordability and sustainable human resource development. Renewable energy technology requires a significant capital investment and this must be accounted for in the financial arrangements of the project. However the life cycle cost of extending utility power is higher and will be loss making for the power utility involved. Other points are as follows:

i) The renewable energy hybrid system offers a new approach whereby an affordable service can be provided to all of the villagers.

ii) This project seeks to specifically build in sustainability and support as a key part of the project itself. Sustainability is to be achieved by the development of local economic activity and a training program to build local capability.

iii) Renewable energy technology information needs to be improved. Many prospective producers and users do not understand the technology and therefore are not aware of the potential and advantages of utilising renewable energy systems. This project will assist in overcoming this by the promotion of the project that will be achieved.

PROJECT IMPLEMENTATION

The project will be implemented in stages by the participating groups through a consortium approach; ie, the Australian contractor (AES), BPPT, and an Indonesian partner company (PT LEN) of Bandung. The project will be implemented as follows:

1 The main participants will form a project management committee to oversee the project. This committee will include a membership to the National Utility, PLN, such that the provision of a hybrid system to each region can be carried out without potentially conflicting with any existing PLN programs.

2 PT LEN will lead the role of coordination with the KUDs and assist in local planning for shipping, freight and general transport requirements.

3 In each region where systems can be operated on a cluster basis there will be appointed a central service company acting in conjunction with the KUDs. This company will attend to local service and support of the systems by holding spares and any necessary components.

4 PT LEN will routinely receive status reports on performance of the cluster in their area. It is expected that only five to seven such agents will be appointed. This greatly simplifies the maintenance requirements and enhances the sustainability of the power systems.

5 Each KUD will enter into an agreement for the system to be installed and manage a basic level of service and liaison. This will include purchase of stored value cards and distribution to the households.

6 The project management committee will monitor and manage this process over the three year installation phase.

7 By staging the installation carefully over the three years it is expected that the transfer of skills and expertise will be very successful.

FINANCIAL ANALYSIS

A standard financial analysis has been carried out on the proposed project. The basic power systems are classified as System A and System B. These systems have been designed to meet the electrical loads in typical villages of 100 and 200 houses respectively. A detailed energy analysis has been undertaken to confirm that the designs will reliably operate villages in the range of 75 to 125 and 150 to 250 houses. Tables 1 and 2 attached provide more specific design detail.

A range of base data points and some assumptions have been made for the project. These are as follows:

- The average village is 200 houses with 5.2 people per house
- The ability to pay is set at 13600 Rps per month per household
- Systems will be installed with two sizes:
  System Size A is for 75 to 125 houses/village
  System Size B is for 125 to 225 houses/village
- The average energy consumption per house per day is 250 Watthours
- The peak available power per house is 200 watts
- A constraint is placed upon the appliances that may be used in households
- Power is available for industry; ie, crafts, fishing and other services
- Each system will cost approximately US$154,000 with other costs to be defined
- The life of the systems is 20 years
- Value of the fixed plant at the end of the period is nil
- Reduction in the multiple use of small diesels will reduce noise and pollution
- Each newly connected household will save on kerosene, paraffin and battery costs
- A cluster of five to ten systems will be installed in a local region so as to minimise operating costs and achieve effective training of staff
- It is assumed that 80% of the households will buy electricity regularly
- Electricity will be sold to industry enterprises separately

The results from the design of the systems has been thoroughly evaluated using computer based simulation techniques. This approach has been proven at AES over a ten year period.

An associated FIRR over the arrangement terms of a 7 year grace period and 25 years repayment has been calculated. This shows an actual FIRR of -2.52%. Sensitivity analyses have been carried out as required within the AusAID appraisal guidelines.

ECONOMIC ANALYSIS

The economic analysis has been carried out over the planned twenty year lifetime of the project itself. This has been chosen as the lifetime of the photovoltaic modules and the inverter control system itself.

The following economic costs have been identified:

a) The project will impose new minor costs in terms of recycling components that have exceeded their useful lifetime. Batteries are one such item. Indonesia has a battery manufacturing industry and there already exists a battery recycling program. Industry

designated collectors will pay for spent batteries and then return them to the manufacturer for recycling.

It is recognised that disposal of batteries will need to managed appropriately. It is suggested that this issue is not difficult in the case of hybrid systems given that a centralised approach is adopted and that each power system operates under a service agreement.

b) The operation of the systems will impose costs in terms of land use, investment in training and procedures as well as the need for safety training in handling heavy items such as engines and batteries.

c) There are existing household energy budget costs, especially in the area of batteries, paraffin and kerosene. These costs are currently met by the villagers and will be displaced by electricity supplied by the new hybrid system.

A number of economic benefits have been identified as accruing from the project. These are:

a) Industry development

In this area it is calculated that there will be an increase in net income successively each year due to availability of electricity. Typical areas include refrigeration for fishing and consequent sale of high quality fish, local crafts and arts, small scale tourism and local economies in general such as stores and consumer goods.

b) Education

Educational benefits accrue in two key areas. Firstly the availability of electricity for schools will greatly enhance the learning process. Secondly, households with lighting will offer far superior home learning facilities.

c) Environment issues

A range of benefits will accrue in regard to the environment benefits. This includes a reduction in both transport costs and future emissions from conventional power plant.

d) Health

This project will introduce net positive benefits in the area of health and health care. In the households in each village there is a current practice of burning firewood, kerosene and use of lead acid batteries for home lighting. The burning of wood and kerosene releases airborne pollutants which have been shown to have a detrimental effect on health. The hybrid system will provide clean electrical lighting for households, thus overcoming this problem. The use of batteries can lead to spillage of sulphuric acid which is also a health hazard within the home.

The supply of electricity will also be made available to health clinics where refrigeration of medicines will provide for an improved level of health care overall. The hybrid systems will show their full effect in health care in the fourth year when all systems are installed and operational.

e) Recreational

One of the problems of maintaining the family unit in rural areas is the lack of personal interests that may be broadly termed recreational interests. The provision of electricity will enable local entertainment via communications and the use of radio/TV/stereo units. Coupled with much improved evening lighting this facility brings a net positive value to the village.

f) Households

There will be an economic benefit accruing to each household as a result of having a safe and reliable electricity system. Higher quality lighting and basic amenities in the house such as low powered fans for cooling will generally enhance the quality of life for each family. Pursuits such as reading will be facilitated and this benefit will also be linked to improved educational outcomes for the village overall. It is believed that these benefits will accrue primarily to adults and especially to women who have the major responsibilities for home management.

The EIRR for the project has been calculated to be 22.4%. The calculation has been carried out over the life of the system which is estimated to be 20 years. A number of the economic benefits will however extend beyond this 20 year period. Sensitivity analyses have been carried out as required within the AusAID appraisal guidelines.

IMPLEMENTATION SCHEDULE

Planning and Implementation

As previously discussed it is proposed that the project be carried out over a three year period with a scale up of installation activities over that time. This approach would assist in minimising any difficulties encountered in establishing all aspects of the project. These aspects include securing an adequate transport system, setting up local training, avoiding difficulties in coordinating installation over the various weather patterns in Indonesia and other such matters.

Implementation Stage

- Final survey to select location
- Lease/purchase contract agreement between users and KUDs or appointed bank
- Hardware procurement and delivery
- The consortium will agree on the appointment of the team to be trained for the installation
- Hardware installation will be carried out under the supervision of the supplier and the organising committee
- Commissioning will be conducted by the consortium, KUD or similar body and local government team

ORGANISATION/MANAGEMENT SYSTEM

In this project a well organised project plan covering the hardware delivery, distribution and installation will be developed. There is a need for the local management organisation to collect the regular instalments from the users. The local KUD will implement the program at the village level.

During the repayment period BPPT will enter into appropriate arrangements with the KUDs who will effectively own the power systems. The KUDs, with support from BPPT, will contract the local commercial partner (PT LEN) to support the systems.

RISK ASSESSMENT

Several risks may be considered to exist within the framework of this project. It would however be useful to outline a number of areas which are **not** considered to be risks:

1 The technology and products are not considered to be a risk. The systems are standard products which have been developed, evaluated and field proven over a period of ten years.

2 The partners are key participants have long developed expertise in their respective countries. BPPT is well known and their expertise in these types of projects has evolved over many years. AES has been established for ten years but the founders' involvement in renewable energy began in 1980.

3 Cost trends will work strongly to assist this project. It is predicted that solar energy equipment will continue to reduce in cost in the coming years while fossil fuel costs are expected to gradually increase.
4 The demand for electricity will continue to rise in the future and the service as proposed will not become redundant.
5 Environmental issues in regard to atmospheric warming will increase as a problem and developing countries will progressively be requested to use cleaner technologies.

Project Risks:

There are two main risks associated with the project:

- project management arrangements
- the ability/willingness of the end users to pay

These risks have been accounted for in the sensitivity analyses and the general financial models.

The project management risk is one that is under the control of the project management team itself. The effective management of the installation, commissioning and handover processes must be carried out efficiently and effectively at all times. A skilled manager will be used for this task.

The other risk relates to payment for the electricity itself. In this case prepayment cards are to be used to ensure payment for the power. This approach overcomes the problems of non payment for delivered energy. The prepaid cards can be used as currency and processes must be put in place to protect against loss or theft.

PROJECT SUSTAINABILITY AND TRAINING

The ongoing sustainability of the project remains the key aspect in regard to the monitoring schedule and overall responsibilities and therefore further description is provided in regard to the training and its application. Training for the villagers and more particularly for the local service agencies will be provided in Perth.

The project management group will formulate and conduct the training courses for the hybrid system end users. Australian and BPPT personnel will supervise the installation and commissioning on site for each system.

Full system training is to be provided to the regional agents on a cluster basis. All villages will receive basic training in system functions and capabilities. It is also planned that local government agencies will be included in aspects of the training sessions. This is to improve the overall exposure of the systems and promote the technologies within each region.

The training sessions will include the following broad areas:

i) General description of the hybrid system
ii) Operation and maintenance of the system
iii) Organisation and management
iv) Revenue collection and smart card distribution procedures

The hybrid system needs to be provided with clear and easy to understand documentation. With this information the project implementation team will provide training on technical management to the cluster agencies. The training will be implemented from an early stage of the project such that the agencies and the village end users will be familiarised with the systems.

CONCLUSION

The proposed rural electrification project for Eastern Indonesia will be the largest application of hybrid energy systems technology implemented to date. The project has been planned and developed over a four year period with specific attention given to the economic benefit accruing at village level.

System cost recovery has been a crucial part of the development process. Due to the small number of kWh consumed by each household the total monthly tariff is expected to be well within the financial capability of the villagers.

Based upon final approval from the financial underwriters the project is expected to commence in December 1998.

Table 1 - Inputs for Systems A and B

		System A					System B				
1	No of Houses	75	100	125			150	200	250		
	No of Villages	12	12	12	36		12	12	12	36	
2	Daily System kWh	31.57	41	50			62	78	99		
3	Design kW / day	7	8	10			11	11	11		
4	Engines hours/day	2	3	4			4	5	6		
5	**Components**		**Cost**	**Energy kWh/d**	**Years**	**M+O ($)**		**Cost**	**Energy kWh/d**	**Years**	**M+O ($)**
a)	**Photovoltaics**		($/Wp)								
	Array kWp	6000		30.00			8000		40		
	$ / W	6.16					6.16				
	MO per year					154					250
b)	**Diesel Engines**		($)								
	Replacement hours	25000	11165		20		20000	11165		20	
	Major overhaul	12500	4620		20	135	10000	4620		11	421.58
	Minor overhaul	5000	1155		14	84	5000	1155		5	210.79
	Service	500	154		1	112	500	154		1	281.05
	Hours per day	2					5				
c)	**Battery**										
	Lifetime in years	5					5				
	Annual M+O	2	77			77	2	77			77.00
d)	**Inverter**										
	Lifetime in years	20					20				
	Annual M+O		231			231		231			231.00
e)	**Reticulation**										
	Lifetime in years	20					20				
	Annual M+O		193			193		193			192.50
f)	**Fuel / day (litres)**	**kWh/l**	**litres**	**Cost**	**hrs/day**		**kWh/l**	**litres**	**cost**		
	75 houses	40.22	0.79	0.30			5.93	10.45	4.02		
	100 houses	7.48	5.47	2.11			4.29	18.23	7.02		
	125 houses	4.95	10.16	3.91			3.53	28.06	10.80		
	Cost fuel per litre		0.39					0.39			
g)	**Annual O + M**	kWh			Total	986				Total	1663.91
					$/kWh	**0.09**				**$/kWh**	**0.13**

Table 2 - Technical Data for Systems A and B

	System A	Single Phase		
1	No of Houses	75	100	125
2	No of Villages	12	12	12
3	Load Composition	Hours	Wh/day	
	Lights 4* 10 watts	5	90	
	Radio 1* 5 watts	8	40	
	TV 1*12 watts	6	72	
	Averaged Total		200	
4	People per house	5.2	5.2	5.2
	Watts pk/ house			200
5	Houses / Village	75	100	125
	People served	4680	6240	7800
				18720
	Growth Margin			20%
6	Design kWh / day	31	40	50
	a) Domestic	18	24	30
	b) Industry	14	17	21
7	Daily System kW	7	8.3	9.6
8	Load Growth Margin			30%
	Diversity Factor			70%

System B	Single Phase		
No of Houses	150	200	250
	12	12	12
Industry Power			
	No Units	kWh/d	kW
Ice making	2	8	1
Craft tools	10	5	1
Clinic	1	0.5	0.2
School	1	0.8	0.5
Area lights	5	2	0.5
Communications	1	1	0.2
	150	200	250
	9360	12480	15600
			37440
Growth Margin			20%
Design kWh / day	62	78	98
a) Domestic	36	48	60
b) Industry	26	30	39
Daily System kW	10.9	13.5	16.1
Load Growth Margin			30%
Diversity Factor			70%