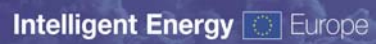


EIE-06-256 REEPRO



# **Promotion of the Efficient Use of Renewable Energies in Developing Countries**

**International Appropriate Technology Scan**

## **Authors**

Antje Klauß-Vorreiter, DGS e.V,

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## 1 Introduction

The REEPRO project is motivated by the fact that poor households in Developing Countries often lack access to basic energy services. Currently the situation for many rural communities of developing countries is characterized by energy poverty and stagnation. The REEPRO project shall lead to the provision of energy services to those currently un-served or underserved by higher quality energy services on the basis of an introduction of renewable energies and energy efficiency. To achieve the overall objective, the development of a RES training kit in 3 levels is pursued, which targets country RES stakeholders with different educational background from RES experts (1) over technician (2) to community stakeholders (3).

Training kits including text books, teaching material and teaching descriptions will be developed for the subjects: Power Transmission and Storage, Biogas, Biofuels, Gasification, Photovoltaic, Solar Thermal, Entrepreneurship, Financing, RES Policy Planning, International Trade, Project Development. The trainings will be performed in lectures and workshops. The training kits will be developed based on the adaptation and further development of existing guidebooks in order to comply with the local situation of the targeted countries. Local data collection is very important in this step. It serves for shaping the content of the training documents. Several types of data need to be collected: socio economic study, educational competence scan (finance and economics), educational competence scan (technology understanding), appropriate technology scan and financial tool scan.

For the demonstration of best-practices not only Cambodian and Lao best-practice projects will be presented but also projects from third countries. Those projects are probably not transferable to Laos and Cambodia but should show the trainees how individual solutions can tackle the demand of specific locations. They should widen their mind.

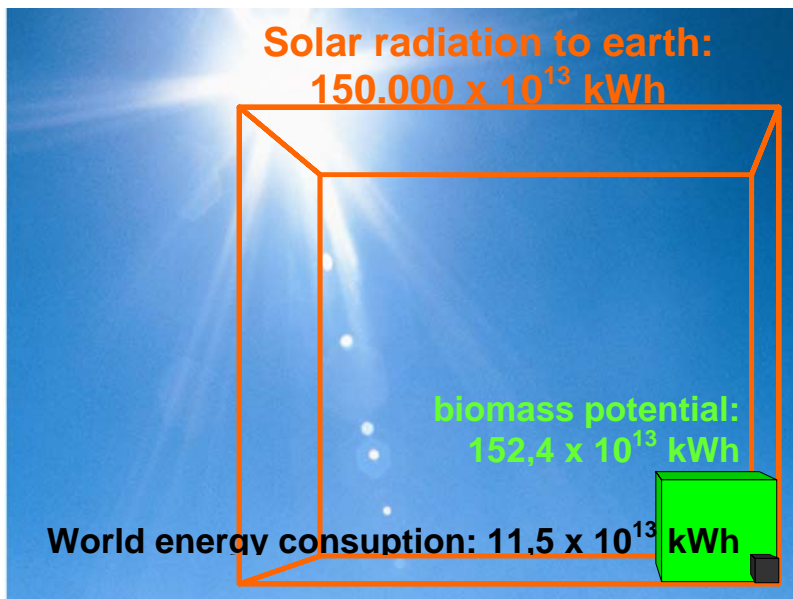
The presented paper is the first version, the project team will ongoing collect information on best practice projects and update the presented paper frequently.

## 2 Renewable Energy Sources considered within REEPRO

Renewable energy sources also called non-conventional energy, are sources that are continuously replenished by natural processes. For example, solar energy, wind energy, bio-energy, bio-fuels, hydropower etc., are some of the examples of renewable energy sources (RES). A renewable energy system converts the energy found in sunlight, wind, falling-water, seawaves, geothermal heat, or biomass into a form, we can use such as heat or electricity. Most of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted, and therefore they are called renewable.

### 2.1 Solar Energy

Solar energy is the most readily available and free source of energy since prehistoric times. It is estimated that solar energy equivalent to over 13,000 times the world's annual commercial energy consumption reaches the earth every year.



**Figure 1: Energy consumption vs. Biomass and solar energy potential**

Solar energy can be utilised through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun's heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

### 2.1.1 Solar Thermal Energy Application

In solar thermal route, solar energy can be converted into thermal energy with the help of solar collectors and receivers known as solar thermal devices.

#### Solar water heaters

Most solar water heating systems have two main parts: a solar collector and a storage tank. The most common collector is called a flat-plate collector. It consists of a thin, flat, rectangular box with a transparent cover that faces the sun, mounted on the roof of building or home. Small tubes run through the box and carry the fluid - either water or other fluid, such as an antifreeze solution - to be heated. The tubes are attached to an absorber plate, which is painted with special coatings to absorb the heat. The heat builds up in the collector, which is passed to the fluid passing through the tubes.

An insulated storage tank holds the hot water. It is similar to water heater, but larger is size. In case of systems that use fluids, heat is passed from hot fluid to the water stored in the tank through a coil of tubes. Solar water heating systems can be either active or passive systems. The active system, which are most common, rely on pumps to move the liquid be-

tween the collector and the storage tank. The passive systems rely on gravity and the tendency for water to naturally circulate as it is heated.

### **Solar Cooker**

Solar cooker is a device, which uses solar energy for cooking, and thus saving fossil fuels, fuel wood and electrical energy to a large extent. However, it can only supplement the cooking fuel, and not replace it totally. It is a simple cooking unit, ideal for domestic cooking during most of the year except during the monsoon season, cloudy days and winter months.

#### **Box type solar cookers**

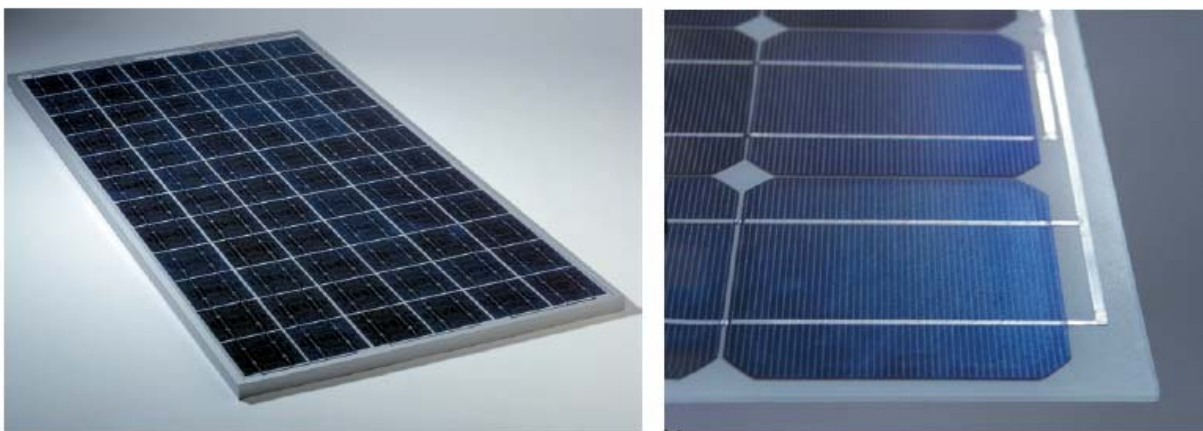
The box type solar cookers with a single reflecting mirror are the most popular in India. These cookers have proved immensely popular in rural areas where women spend considerable time for collecting firewood. A family size solar cooker is sufficient for 4 to 5 members and saves about 3 to 4 cylinders of LPG every year. The life of this cooker is upto 15 years.

#### **Parabolic concentrating solar cooker:**

A parabolic solar concentrator comprises of sturdy Fibre Reinforced Plastic (FRP) shell lined with Stainless Steel (SS) reflector foil or aluminised polyester film. It can accommodate a cooking vessel at its focal point. This cooker is designed to direct the solar heat to a secondary reflector inside the kitchen, which focuses the heat to the bottom of a cooking pot. It is also possible to actually fry, bake and roast food. This system generates 500 kg of steam, which is enough to cook two meals for 500 people.

## **2.1.2 Photovoltaic (PV) - Solar Electricity Generation**

Photovoltaic is the technical term for solar electric. Photo means "light" and voltaic means "electric". PV cells are usually made of silicon, an element that naturally releases electrons when exposed to light. Amount of electrons released from silicon cells depend upon intensity of light incident on it. The silicon cell is covered with a grid of metal that directs the electrons to flow in a path to create an electric current. This current is guided into a wire that is connected to a battery or DC appliance.



**Figure 2: PV Modules**

Typically, one cell produces about 1.5 watts of power. Individual cells are connected together to form a solar panel or module, capable of producing 3 to 190 Watts power. Panels can be connected together in series and parallel to make a solar array, which can produce any amount of Wattage as space will allow. Modules are usually designed to supply electricity at 12 Volts. PV modules are rated by their peak Watt output at solar noon on a clear day.

### **Off-Grid PV Systems**

Completely independent of the grid, the system is connected to a battery via a charge controller. This equipment stores the electricity generated in batteries and acts as the main power supply. An inverter can also be used to provide AC power, enabling the use of normal appliances without mains power. This is important because otherwise the people have to purchase expensive DC equipment or rely on ineffective inverters.

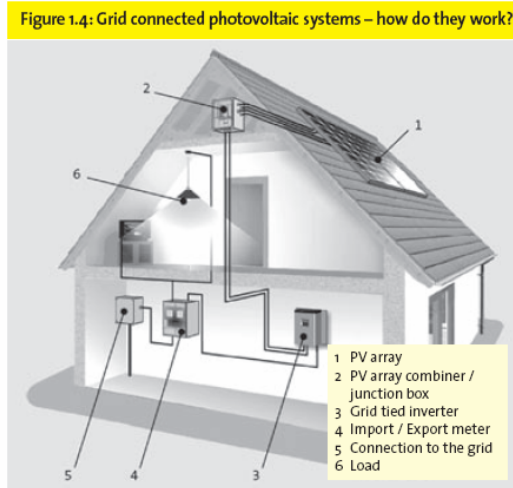
Typical off-grid applications are industrial applications such as repeater stations for mobile phones or rural electrification. Rural electrification means either small solar home systems (SHS) covering basic electricity needs or solar mini grids, which are larger solar electricity systems providing electricity for several households.



**Figure 3: Off grid Solar system (Source SMA)**

## **2.2 Grid Connected PV Systems**

This is the most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment. In countries with a premium feed-in tariff, this is considerably higher than the usual tariff paid by the customer to the utility, so usually all electricity produced is fed into the public grid and sold to the utility. This is the situation in countries such as Germany or Spain.



**Figure 4: Grid connected Solar system**

The electricity (direct current) generated by the solar cells in the PV modules is transported via normal cables to an inverter. This electrical tool, which is often installed somewhere close to the house's connection point to the public grid, transforms the direct current into alternating current in order to make it compatible with the electricity in the house and the public grid. Then there are two options:

1. In countries with an attractive feed-in tariff for solar electricity all electricity generated will be fed after the inverter directly into the grid. The electricity is thereby sold to the utility. The amount of electricity fed into the grid will be measured by a meter in order to get the correct payment from the utility.
2. In countries without an attractive feed in tariff for solar electricity (e.g. a feed-in tariff below the usual consumer prices for electricity) the electricity is in the first place used to cover the electricity demand in the house. By this the electricity bill can be reduced. Only if there is not or not enough demand within the house, the surplus electricity will be fed into the grid.

## 2.3 Bio Energy

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by-products from the wood industry, agricultural crops, raw material from the forest, household wastes etc.. Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel.

### Biogas Plants

Biogas is a clean and efficient fuel, generated from cow-dung, human waste or any kind of biological materials derived through anaerobic fermentation process. The biogas consists of 60% methane with rest mainly carbon-di-oxide. Biogas is a safe fuel for cooking and lighting. By-product is usable as high-grade manure. The biogas can be converted to energy by co-generation.

### Biomass Briquetting

The process of densifying loose agro-waste into a solidified biomass of high density, which can be conveniently used as a fuel, is called Biomass Briquetting. Briquette is also termed as "Bio-coal". It is pollution free and ecofriendly. Some of the agricultural and forestry residues can be briquetted after suitable pre-treatment.

A list of commonly used biomass materials that can be briquetted are given below:

CornCob, JuteStick, Sawdust, PineNeedle, Bagasse, CoffeeSpent, Tamarind, CoffeeHusk, AlmondShell, Groundnutshells, CoirPith, BagaseePith, Barleystraw, Tobaccodust, RiceHusk, Deoiled Bran

### **Biomass Gasifiers**

Biomass gasifiers convert the solid biomass (basically wood waste, agricultural residues etc.) into a combustible gas mixture normally called as producer gas. The conversion efficiency of the gasification process is in the range of 60%–70%. The producer gas consists of mainly carbon-monoxide, hydrogen, nitrogen gas and methane, and has a lower calorific value (1000–1200 kcal/Nm<sup>3</sup>). Gasification of biomass and using it in place of conventional direct burning devices will result in savings of atleast 50% in fuel consumption. The gas has been found suitable for combustion in the internal combustion engines for the production of power.

### **Bio fuels**





Unlike other renewable energy sources, biomass can be converted directly into liquid fuels—biofuels—for our transportation needs (cars, trucks, buses, airplanes, and trains). The two most common types of biofuels are ethanol and biodiesel. Ethanol is an alcohol, similar to that used in beer and wine. It is made by fermenting any biomass high in carbohydrates (starches, sugars, or celluloses) through a process similar to brewing beer. Ethanol is mostly used as a fuel additive to cut down a vehicle's carbon monoxide and other smog-causing emissions. Flexible-fuel vehicles, which run on mixtures of gasoline and up to 85% ethanol, are now available.

Biodiesel, produced by plants such as rapeseed (canola), sunflowers and soybeans, can be extracted and refined into fuel, which can be burned in diesel engines and buses. Biodiesel can also be made by combining alcohol with vegetable oil, or recycled cooking greases. It can be used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines.

### 3 International technology data sheets

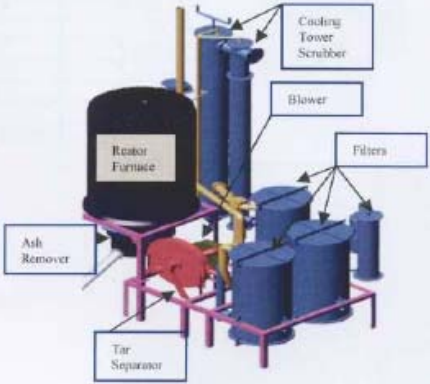

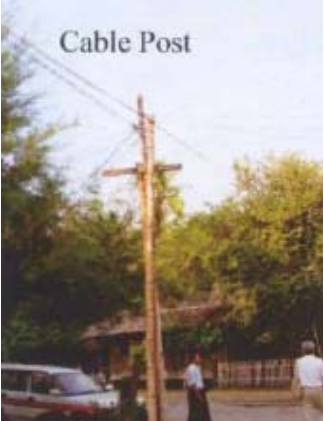

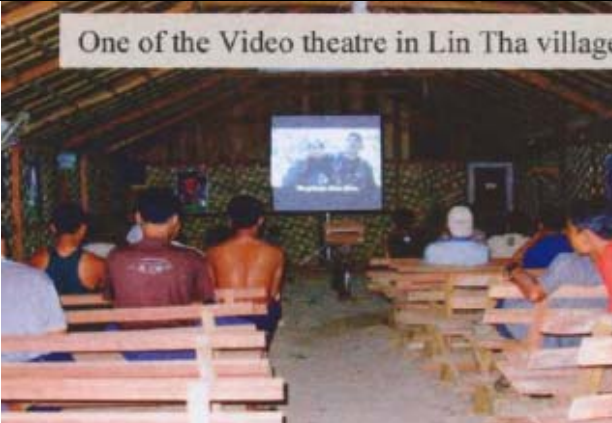

#### 3.1 Biomass – Village biogas grid in Thailand

Type of project: (tick off the type)	PV	Solar Thermal	Biomass to Energy		
			x		
Project name:	Village biogas grid in Thailand				
Location of the plant:	Mu Bang Sosa Nongphan, Chiang Mai province, Thailand				
Year of Implementation:					
Operator: (Name and address)	Local Farmer				
Planner: (Name and address)	Biogas Advisory Unit, Chiang Main University				
Detailed description of the installation: (technology, function, benefit for users, etc. max 150 words)	<p>The biogas plant of a pick farmer in the village Sosa Nongphan, Chiang Mai province, Thailand was implemented as village project. The biogas produced in the plant is piped to 94 village households and used for cooking. The households paid between 400 to 600 THB for getting the gas connection. This money was used for the investment in the gas line. The gas lines were constructed by the villagers, thus the investment for the gas lines could be kept low.</p> <p>Basic information on the biogas plant:</p> <ul style="list-style-type: none"> <li>• Input: Manure from 500 pigs, 100m<sup>3</sup>/day</li> <li>• Gasversorgung: 94 Haushalte</li> <li>• Investment: 2 digester vessels with accessory 200.000 THB (5.700 US\$) per digester. The first vessel was financed partly by the farmer (50%) and the Ministry of Agriculture. The second by the farmer (50%) and the village authority.</li> <li>• The manure is pumped every morning when the stables is cleaned with a lot of water into the biogas plant.</li> <li>• The digested manure is pumped twice a day from the digester into the final storage tank.</li> </ul>				
Generated Energy service: (tick off the energy type)	electricity	heat	gas	light	
			x		
Power output of installation: (kWel, m <sup>3</sup> biogas, kW th, etc.)	Biogas for cooking for 95 households				
Financing (tick off the financing type)	private investment	loan	donation	grant	
	50%			50 %	
Investment costs in US\$	Biogas plant: 11,400 US\$ Gas tube connection: 11,43 to 17,15 US\$ per household				
Maintanance costs in US\$	No information available				
Savings:	No information available				

Energy sale income in US\$:	No information available
Comments:	none
Pictures and graphics	
 <p data-bbox="188 685 469 719">Digested manure tanks</p>	 <p data-bbox="804 685 927 719">Pig stable</p>
 <p data-bbox="188 1039 501 1072">Technical system scheme</p>	 <p data-bbox="804 1039 1126 1072">Gas utilisation for cooking</p>

### 3.2 Biomass - Rural Electrification with rice husk gasifier in Myanmar

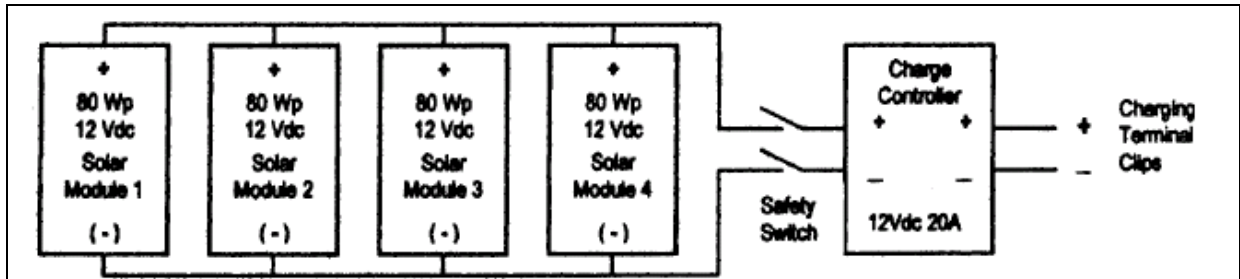
Type of project: (tick off the type)	PV	Solar Thermal	Biomass to Energy		
			x		
Project name:	Rural Electrification with rice husk gasifier				
Location of the plant:	<b>Lin Tha Village, Thandwe Township, Rakhine State, Myanmar</b>				
Year of Implementation:	2005				
Operator: (Name and address)	Operators hired by the plant owner				
Planner: (Name and address)	Myanmar Inventor Cooperative Society (MICS)				
Detailed description of the installation: (technology, function, benefit for users, etc. max 150 words)	<p>A thermal converting process of dry biomass (Rice husk) feedstock into a mixture of gases called producer gas that can be burnt in the internal combustion engines. The electricity is developed from the generator directly driven by the gasifier engine.</p> <p>Benefits from this biomass gasifier system application are: The cost of using rice husk for gasifier is much cheaper than that of using fossil fuel for internal combustion engine getting the same output electrification.</p> <p>It can create the opportunities for the betterment of social and economic conditions of the rural people as the cost of diesel or petrol is too high.</p> <p>It can also enhance the development of new business opportunities for private sector entrepreneurs</p>				
Generated Energy service: (tick off the energy type)	electricity	heat	gas	light	
	X				
Power output of installation: (kWel, m <sup>3</sup> biogas, kW th, etc.)	Engine output: 60 HP Generator output: 30 KW				
Financing (tick off the financing type)	private investment	loan	donation	grant	
	X				
Investment costs in US\$	Building cost: 2,500 US\$ Gasifier Unit: 3,750 US\$ Gas engine: 1,250 US\$ Generator Unit: 1,250 US\$ Electricity main and distribution system: 4,583 US\$ Installation and overhead cost : 2,000 US\$ Total : 15,333 US\$				
Maintenance costs in US\$	Fuel consumption: 1.6 ton/KWh (estimated: 87 tons per year) Man hours for operating and maintenance of the plant: 18615 manhr/year				
Savings:	N/A				
Energy sale income in US\$:	Operation time: 17 hours per day (12 hours rice milling + 5 hours lighting) Energy Sales: N/A				

<p>Comments:</p>	<p>This project has won the 2006 ASEAN Energy Award from ASEAN Center for energy (ACE)</p>
<p>Pictures and grafics</p>	
	
	
	

Source: Asian Energy Awards 2004

### 3.3 PV - Piagapo solar electrification project in Philippine

Type of project: (tick off the type)	PV x	Solar Thermal	Biomass to Energy		
Project name:	Piagapo solar electrification project				
Location of the plant:	<b>Municipality of Piagapo, Lanao del Sur, Philippines</b>				
Year of Implementation:	2003				
Operator: (Name and address)	Beneficiaries from the project				
Planner: (Name and address)	Bytex Information Technology and Engineering Services in cooperation with Department of Energy of the Philippines and Mindanao State University (MSU) Affiliated Nonconventional Energy Center				
Detailed description of the installation: (technology, function, benefit for users, etc. max 150 words)	<p>There are totally 7 stations where installed the project in the Municipality of Piagapo. At each station there are three different designs:</p> <p>Solar battery charging station: it is a 1.28 KW peak 4 channel photovoltaic BCS with identical charging channels. Each channel has a capacity of 300-320 watt peak. It is composed of 4 solar modules per channel.</p> <p>Solar street light: it is composed of a 75 watt peak polycrystalline solar module, 100 ampere-hour automotive battery, 6 ampere battery control unit, 20 watt florescent lamp and anti-theft frames for solar module and battery</p> <p>Solar home system: it is composed of a 75 watt peak polycrystalline solar module, 100 ampere-hour automotive battery, 6 ampere control unit, 24 watt micro inverter, 2 AC compact florescent lamp (11 &amp; 9 watts) and anti-theft frames for solar module and battery</p>				
Generated Energy service: (tick off the energy type)	electricity x	Heat	gas	Light	
Power output of installation: (kWel, m <sup>3</sup> biogas, kW th, etc.)	Solar battery charging station (7 stations): 8.58 KWp Streetlights (7 stations): 1.05 KWp Solar home system (7 stations): 0.525 KWp				
Financing (tick off the financing type)	private investment X	Loan	donation X	Grant	
Investment costs in US\$	9,185 US\$ (for one channel PV battery charging station only - remember that there 4 channels per station and there are totally 7 stations implemented by this project)				
Maintanance costs in US\$	1,177 US\$ per year (for operation and maintenance)				
Savings:	N/A				
Energy sale income in US\$:	3129 US\$ per year				
Comments:	---				
Pictures and grafics					



Schematic diagram of one 320-Wp charging channel



Two of 4 channel of the solar battery charging station



Solar street light and entire 4 channel solar battery charging station

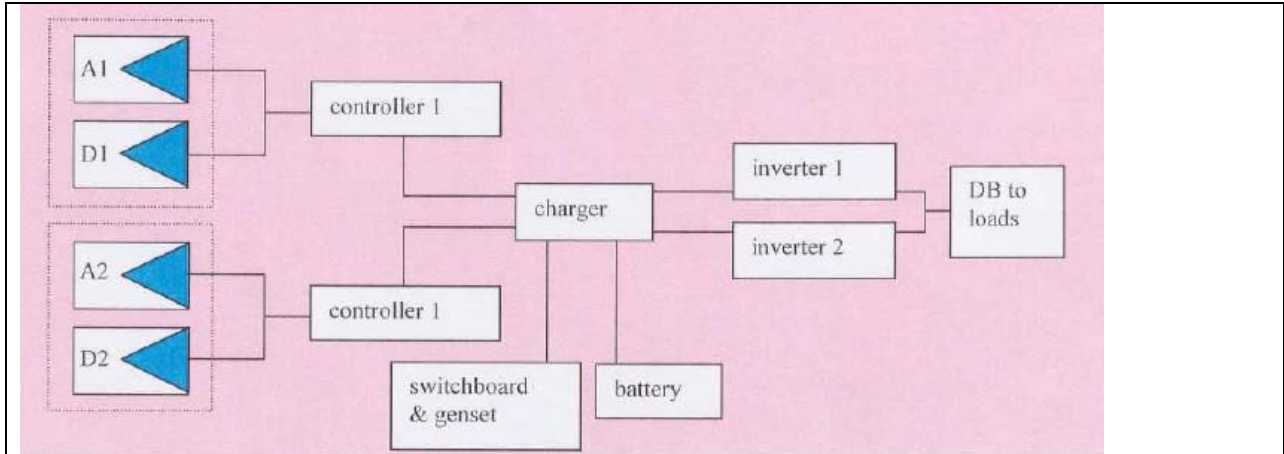


Solar module mounted on top of a mosque as part of solar home system

Source: Asian Energy Awards 2004

### 3.4 PV - Solar photovoltaic diesel hybrid system in Malaysia

Type of project: (tick off the type)	PV	Solar Thermal	Biomass to Energy		
	x				
Project name:	Solar photovoltaic diesel hybrid system				
Location of the plant:	Nature Education and Research Center (NERC) at Endau Rompin National Park, Johor, Malaysia				
Year of Implementation:	1998				
Operator: (Name and address)	Staff of NERC				
Planner: (Name and address)	Local company				
Detailed description of the installation: (technology, function, benefit for users, etc. max 150 words)	<p>The system uses 112 modules giving a peak capacity of 10.08 KWp. The operating voltage is 48 VDC. There are 24 battery cells at 1525 Ah per cell and the diesel generator rating at 7.5 KVA. The system designed using a 74:26 ratio between solar and diesel contribution in terms of energy requirements. Accompanying equipments include two 100 A charge controllers and two 3.5 KVA inverters.</p> <p>The load of the NERC includes power for residential type electrical equipments, such as lights, TV, radio, freezer, refrigerator and computers accounting for 27.4 KWh per day.</p>				
Generated Energy service: (tick off the energy type)	electricity	heat	gas	Light	
	x				
Power output of installation: (kWel, m <sup>3</sup> biogas, kW th, etc.)	17,479 KWh per year				
Financing (tick off the financing type)	private investment	loan	donation	grant	
	x		X		
Investment costs in US\$	630,710.80 RM (approx. 165,990 US\$)				
Maintenance costs in US\$	N/A				
Savings:	No				
Energy sale income in US\$:	No				
Comments:	---				
Pictures and graphics					



Wiring diagram of the hybrid system



Part of the NERC complex



Library



PV array



Genset and battery bank

Source: Asian Energy Awards 2004

### 3.5 PV - Community Water Supply Project in Thailand

<b>Type of project:</b> (tick off the type)	PV	Solar Thermal	Biomass to Energy	
	X			
<b>Project name:</b>	<b>COMMUNITY WATER SUPPLY PROJECT</b>			
<b>Location of the plant:</b>	Ban Nam Wa, Nam Phang Sub-District, Nan Province, Thailand			
<b>Year of Implementation:</b>	2005			
<b>Operator:</b> (Name and address)	Nam Phang Tambon Administrative Organization			
<b>Planner:</b> (Name and address)	Nan CBO Research Centre, Thailand			
<b>Detailed description of the installation:</b> (technology, function, benefit for users, etc. max 150 words)	Traditional water supply was through drawing water from the Wa River. However, due to environmental problems (erosion and use of chemicals in agriculture being washed into the river) the water was not really fit for human consumption. Through community involvement, a decision was made to get water from a nearby spring in the forest. A submersible pump set and piping was installed with a 40 cubic meter storage system built in the village. A solar PV system (14 panels - 120 Wp) was installed to power the pump. The system is operated by a village committee and technical support, if needed, is provided by the Nan CBO Research Centre as well as the Nam Phang Public Health Station.			
<b>Generated Energy service:</b> (tick off the energy type)	electricity	heat	gas	light
	X			
<b>Power output of installation:</b> (kWel, m <sup>3</sup> biogas, kW th, etc.)	1.68 kWp for the solar PV system			
<b>Financing</b> (tick off the financing type)	private investment	loan	donation	grant
	In kind			XXXXXX
<b>Investment costs in US\$</b>	Approximately 15,000 USD of which 12,774 was provided by the GEF Small Grant Program of UNDP			
<b>Maintenance costs in US\$</b>	Unknown but mainly in kind for repairs of the piping, maintaining the well, cleaning of the system, etc.			
<b>Savings:</b>	Not determined yet. However, the community is now able to produce chemical free vegetables for own use as well as for income generation. Initial experiences show a reduction in power costs for the water supply of about 40 USD per month.			
<b>Energy sale income in US\$:</b>	People pay 2 Baht per cubic meter of water used			
<b>Comments:</b>	The project has resulted in strengthening the community and the capacity of the community members to build and maintain the system. Households, the school and other community based institutions are able to use safe water and are able to build up an "emergency" fund due to savings obtained in the water supply system. The installation of the system has resulted in considerable interest from other communities and several similar systems are being installed at the moment.			

**Pictures and grafics**



The spring in the forest



The solar PV system in the village



The water storage system in the village



Happy producers of clean and chemical free water in front of their vegetable garden.