FINAL DISSERTATION

MSc "Energy Systems and Environment"

Title: "IMPROVEMENT OF SHS PROJECTS IN DEVELOPING COUNTRIES"

Author: Carlos Monge Barrio

September 2001

"Is great to know all the people

that I knew during this year.

For you all,

Cheers!!!!"

INDEX

ABSTRACT

The porpoise of this project is to improve the Solar Home Systems used in the developing countries for the rural electrification. This is done firstly by a previous literature review to get know the context in which this project are realised. Then is done a selection of two norms to evaluate the ongoing project, the first one evaluate the technical matters of the system and the second one the management and social factors of the projects, very important in this type of projects. From the evaluation, it is obtained the proposed improvements and eventually the conclusions.

1. OVERVIEW OF THE ENERGY SITUATION IN THE RURAL AREAS OF DEVELOPING COUNTRIES.

1.1 Introduction

Energy Market situation in many developing countries is far to be good, particularly in the rural areas, where nearly 2 billion people do not have even electricity access to fuels such as oil and gas. The problem is likely to be worse in the nearly future. The population of the developing world is expected t increase by 3 billion over the next forty years, and also the demand per capita will grow rapidly.

Although grid electrification is the traditional means of providing reliable electricity supplies, connection to distant grids will be too expensive to be cost effective for many rural areas. Fortunately, there are a number of promising alternatives for increasing energy supplies even in the very remote areas, ranging from more efficient in use of traditional fuels to advanced technologies based in renewable energy sources.

One third of all energy consumed in the developing world comes from biomass. In addition to being their primary source of energy, biomass also provides a good source of incomes to many people in the developing world. In Africa alone, the production and marketing of wood fuels is a $5 billion business that employs more than 400,000 people. Wood and other traditional fuels such as dung have numerous disadvantages however. They are far less efficient than other energy sources; a kilogram of wood, for example, generates only one-tenth of the heat yield by a kilogram of liquid petroleum gar (LPG). Moreover, burning these types of fuels in an enclosed, poorly ventilated space present a major health hazard. According to some estimates, smoke contributes to acute respiratory infections that affect 4 millions infants and children a year. The use of wood has also taken a serious toll on the environment in many regions, leading to deforestation, soil erosion, and reduced soil fertility. Many children and adults in developing countries must spend up to several hours per day gathering fuel; this leaves them less time for schooling and productive activities and thus perpetuates poverty.

In poor countries with annual per capita incomes of 300$ or less, at least 90 per cent of the population depends on wood and dung for cooking. But the people move up as their incomes grow, eventually switching to electricity for lighting and fossil fuels for cooking, in agriculture and industry, diesel engines and electricity replace manual and animal power. The transition to modern fuels is usually complete by the time annual per capita incomes reach $1000-$1500. With technological progress and reductions in the cost of modern fuels, the income level at which people make the transition can decline significantly. For example, a transition that took nearly 70 years in the United States (1850-1920) took only 30 years in Korea (1950-1980). But such transitions will not happen overnight. Even in East Asia and the Pacific, a region that has experienced rapid economics growth and significant increases in the supply of commercial energy, biomass still accounts for 33 per cent of energy supplies and its use is expected to decrease by only 50 percent over the next 15-25 years.

1.2 Energy supply; trends and options

Because biomass use will continue throughout the developing world for some time, energy policies must support ways to use wood fuels more efficiently and sustainable, while creating the necessary conditions for supplying modern fuels to those who lack them.

1.2.1. Farm forestry and local forest management

Farm forestry (planting trees, shrubs, and grasses on farmlands and between crops) and forest management has long played an important role in alleviating wood shortages in China, India and many other countries. Because farmers outnumber foresters in most countries by several thousand to one, involving them in planting trees and shrubs can dramatically accelerate reforestation. And the incentive to participate in farm forestry programs is strong: wood fetches a high price in some urban markets, and trees and shrubs can supply farmers with fodder, building materials, green mulch, fruit, and other by-products that may be as valuable as the firewood itself.

Experience suggests that effective management of existing forest resources depend on letting local people take responsibility for forest or woodlands. Some successful participatory effects have now been pioneered in several countries. In these programs, farmers get to sell all the wood extracted from the local woodlands; however, that must participate in a resource-management program developed in collaboration with the national forestry department.

1.2.2. Improved charcoal efficiency

Charcoal represents an intermediate rung on the energy ladder between wood and kerosene or LPG. It burns without smoke or dangerous flames and requires only a simple stove whose heat output is relatively easy to control. However, local charcoal producers often use inefficient charcoaling kilns that consume more wood than necessary. Programs promoting technical innovation have been most successful when accompanied by the forest-management programs, which give villagers custody of local forest resources.

1.2.3 Efficient use of biomass

One way to improve wood fuel use is for governments to encourage the private sector to develop and market improved stoves in rural areas by supporting stove design and testing and conducting publicity campaigns and training programs. Relatively simple and inexpensive stoves can reduce the amount of fuel needed for cooking by as much 30 per cent, yield substantial health benefits, and free women and children from hours of gathering firewood.

Although fuels from biomass are generally much less efficient for cooking than modern fuels, biogas derived from digesters of dung and farm residues is an exception. China and India have done much to develop biogas and encourage its use. However, only farmers who raise livestock can easily acquire biogas; it is thus a cost-effective option for less than 10% of most rural populations.

1.2.4. Rural electrification

Rural demand for electricity comes mainly from households that use electricity for lighting and from farms, agroindustries, and small commercial and manufacturing establishments which use electricity for productive purposes such as irrigation pumping, water supplies, crop processing, refrigeration, and motive power. Most rural electrification programs have focused on connecting rural areas to national or local grids. However, grid supplied electricity is not the lowest cost alternative under all conditions. For example, technologies involving wind power, solar thermal power, photovoltaics, and small scale hydropower merit more attention from policy makers.

They are often an ideal way to get energy to rural areas and have significant environmental advantages relative to fossil fuels. Solar power is a particularly attractive option for the countries with abundant sunlight and a poorly developed rural grid electrification system.

The costs associated with these technologies, once prohibitive, have decreased significantly over the past decade. Today, PV systems supply electricity economically to rural areas throughout the developing world for lighting in homes and schools, domestic appliances, refrigeration in health clinics, village water pumps, telephones and street lighting.

1.3 Rural Energy Policies

Evidence suggest that the people are willing to spend a significant portion of their incomes on higher quality energy that improves their quality of live and enables them to be more productive. Governments have an important role to play creating conditions that provide consumers with more energy choices and encourage innovation and investment in new technologies. Prices should be liberalised to reflect costs, and regulatory policies need to encourage competition and level the playing field for all types of energy markets, whether there are served by public utilities, private firms, or community enterprises. For example “off grid” power companies and co-operatives are often totally excluded by electricity regulations from serving people, and policies that artificially hold down prices sometimes provide little incentive for such local initiatives to get started.

1.3.1. Pricing and market reforms

In general energy subsidies (prevalent in developing countries) should be avoided. Subsidies undermine incentives both for consumers to make least-cost choices and for investors to develop alternative energy forms, and more often disproportionately benefit higher income households, which use more energy than poor households.

1.3.2. Alleviating problems with first costs

In developing countries, the first costs associated with getting access to modern sources of energy are often prohibitively high for the rural poor, who are also usually unable to obtain a credit.

There are two ways of dealing with the high initial costs of rural energy services; lowering system costs through design innovations and giving rural consumers access to credit.

1.3.3. Emphasising participation and institutional development.

Local participation is crucial for the success of rural energy policies. Co-operatives, NGO's and community organisations can be highly effective vehicles for supporting the delivery of energy services and managing resources.

1.3.4. Creating enabling conditions

Investment in rural energy conditions may falter because of economic conditions. For example, in rapidly developing agricultural regions, electricity helps to raise the productivity of local agro-industrial and commercial activities by supplying motive power, refrigeration, lighting, and process heating. Increased earnings from agriculture and local industry and commerce then lead, in turn, to greater household demand for electricity. However, when development efforts fail because of, say, poor crop pricing, flawed marketing policies, and inadequate roads, programs to improve electricity supplies are also likely to languish.

2. OPTIONS FOR RURAL ELECTRIFICATION

Between 1970 and 1990, nearly 1.3 billion people, 500 million of them in rural areas, were newly supplied with electricity from national grids. But the population in some developing regions grew faster than electricity supplies. The number of people in sun-Saharan Africa with electricity increased by only 18 million between 1970 and 1990, while the total population grew by 119 million. Similarly, in South Asia, 140 million people gained access to electricity during the same period, but, because of population growth, the number of people without service grew by more than 100 million.

Surveys of rural energy use show that many people spend significant sums on candles, kerosene, and batteries for lighting their homes. Many rural people in Bolivia, for example, spend $4-$5 per month on candles. Switching to electricity and using just 40-watt bulb or a 20-watt incandescent lamp cost a few more dollars more per month but would provide 25 to 75 times more light than a candle.

2.1 The Choices

Many people without electricity in rural areas are therefore willing to pay to get it. Grid supplies are usually the cheapest option in areas with high load densities, as well as in areas near the grid. But connecting small isolated villages to a grid can be expensive because of the necessary investment in transmission lines, poles, transformers and other infrastructure. In some instances, other options: including diesel generators, renewable energy and hybrids, is more cost effective.

2.1.1. Grid Electrification

The high initial cost of grid electrification can be reduced considerably if design standards suitable for areas with less demand are used. Most rural consumers need form 0.05 kilowatts to 0.5 kilowatts, much less than the typical minimum service connection ratings in developing countries utilities. The cost of the installation and wiring provided by utilities are also high, but these can be lowered by simplifying wiring codes and using load limits (circuit breakers) to encourage lower levels of consumption. Other cost-cutting strategies include using cheaper utility poles and involving local people in construction and maintenance.

2.1.2. Micro-grids supplied by diesel generators.

Decentralised isolated distribution systems have been common in remote populations centres for many decades; in most developing countries, they predate the establishment of grids. The cost of such systems typically ranges between 20 and 60 cents per kWh. However, diesel generator can be hard to maintain and expensive to operate because their remote locations and the cost of spare parts and fuel.

2.1.3. Renewable Energy Sources

Energy from solar, wind, and micro-hydropower schemes is an attractive option in regions with the necessary resources. The cost per kWh of electricity generated by micro-hydropower can be as low as 20-30 cents, depending on site; 90 cents for PV panels; and 40-90 for small wind sets. Electricity for local distribution can also be generated from such fuels as biogas and biomass. Micro-hydropower can be one of the cheapest options for providing electricity to rural areas too remote to be connected to a grid.

2.2. Successful Approaches

Countries that have succeeded in making grid electricity service available to rural people have done so through strong public leadership and highly strengthened financial support. There are many ways to pay for rural expansion without destroying the financial viability of the electricity industry.

In Thailand, the public distribution systems serving areas outside of Bangkok, the Provincial Electricity Authority was successful in expanding grid electrification. It dealt with the problems of lower loads in rural areas by extending service first to the highest-load villages, developing low cost connection techniques, and promoting load development. Costs were reduced through standardisation of systems design and provision of financially sustainable lifeline tariff for meeting the minimal requirements of the poorest consumers.

In Costa Rica, rural co-operatives were able to establish a rural grid in the early 1960’s with long-term capital from US Agency of Development and Inter American Development Bank.

A regulatory regime requiring distribution companies to expand service to a blend of high and low income house holds within an assigned territory while requiring full cost recovery for the system as a whole, is a possibility. There are also examples of communities, innovative private companies, co-operatives, and individuals that are successfully distributing electricity through minigrids without subsidies. However, other potential innovations have often been thwarted by regulations and policies that prohibit private enterprises other than the national utility from selling electricity and by the absence of training and technical support. Another policy that discourages private sector participation in rural electrification is uniform countrywide pricing, which effectively makes small local grids financially unsustainable.

3. PV RURAL ELECTRIFICATION

3.1 S.H.S PV RURAL ELECTRIFICATION TECHNOLOGY

3.3.1. Definition

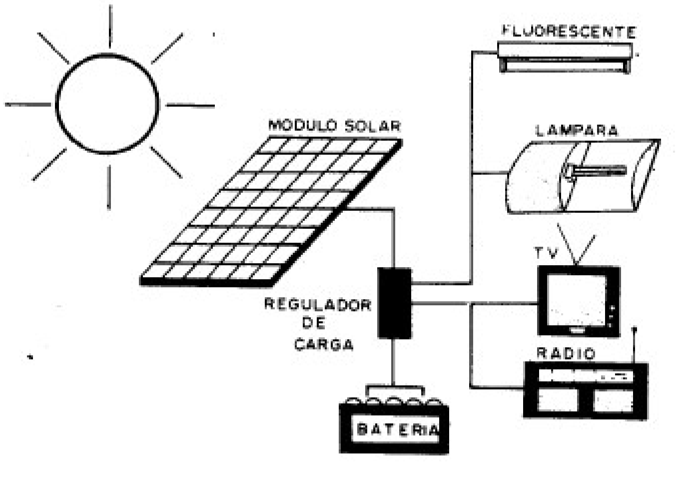
One "Solar Energy System", is also known as "Photovoltaic System", and its defined as the group of components that allow to transform solar irradiation into electrical energy to be provided to a different group of charges (radio, television, lamps,etc...). The photovoltaic systems, design correctly, can supply any energy need: illumination, refrigeration, water supply, communications, etc....

3.3.2. Function of the system.

The photovoltaic panel recibe the sun rays (day light) and transform them into electrical energy.

By means of the charge regulator, the energy generated by the panel, is acondicionated and stored in the battery

The different systems are connected to the charge controller, that manages the energy that comes.

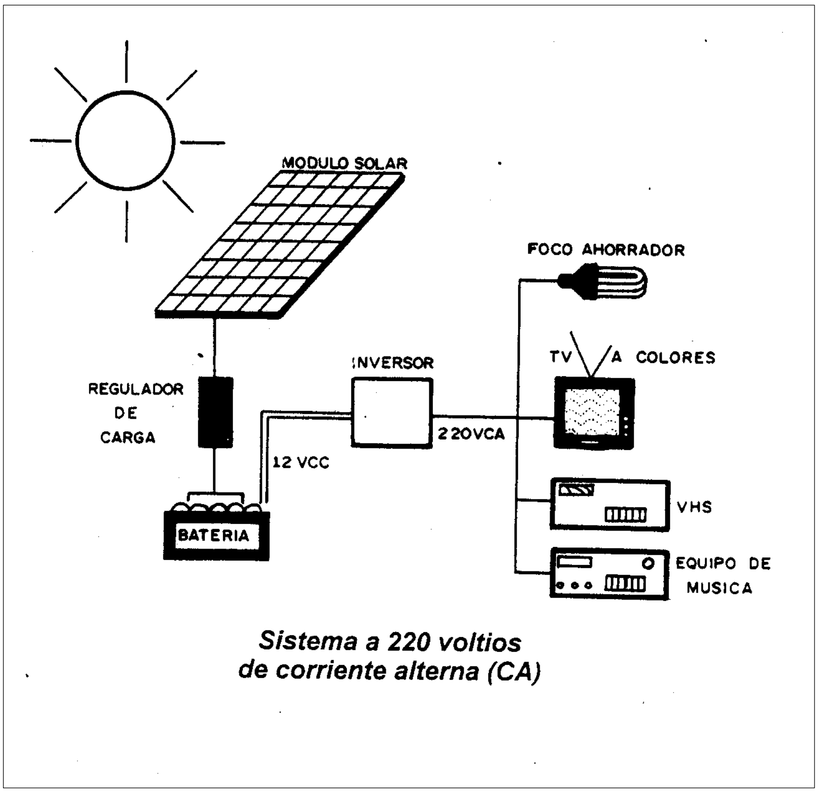


Sistema a corriente continua

A photovoltaic system can supply direct current electricity and in a big range of different voltages (12V, 24V, 48V, etc...) being 12 V the voltage more used, is also possible to get altern current of 110 or 220 V, depending in the equipment of the customers.

It is possible to convert direct current in altern current of 220 V,using an inverter (12Vdc/220 Vac)

A 220 Volts system allows the function of: colour television, VHS systems, small electropumps for water, computers; all this depending of the energy available and the capacity of the inverter.



3.3.3. Components

<u>3.3.3.1 Photovoltaic Panel</u>

A photovoltaic panel is a flat plate, composed by photovoltaics cells, that have the property of converting the energy from the sun into electrical energy.

Depending on the manufacturing process, the modules can be of three types.

1. Monocritalline Silicon.
2. Polycristalline Silicon.
3. Amorphous Silicon.

The first ones are the most efficient.

The panels are manufactured in a wide variety of powers. A system can be composed of different panels. This allows supplying the different energy requirements. Thereby, depending on the needs, it will be selected the number and type of panels necessaries.

3.3.3.2. Charge Regulator:

This is an electronic system which main function is to protect the battery of the overcharge and of the deep discharge, controlling the current entrance from the panel and the exit of current from the battery to the charges.

3.3.3.3. Battery.

The battery is a device that has the function of storage the energy generated by the photovoltaic panel, and provide it to the charges when it is required.

The batteries more widely used because its low cost is lead-acid from the automotive sector. For them, the manufacturer must garantize at least three years util life.

The storage of energy can be useful for:

a. To store the surplus of energy produced during the day to consume at night.
b. To have a reservoir that allows to the consumer use his system in case of various consecutive days with low irradiation.

The storage of energy in the batteries is done by means of reversible electrochemistry reactions, for this is necessary a good quality electrolyte.

$$PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O + \text{Energía}$$

Peróxido de plomo	Plomo	Acido Sulfúrico	Sulfato de plomo	Agua	Electrones
Placa positiva	Placa negativa		Placa positiva y negativa		

DESCARGA →

Ecuación simplificada de las reacciones químicas involucradas en los procesos de carga y descarga.

When the electrolyte is chosen it must be taken into consideration the wheater of the area where the system is going to be installed.

<u>3.3.3.4. Lamps</u>.

There are in the market lamps and fluorescent designed for working directly with direct current, normally they work at 12 V.

Their main characteristics are their low energy consumption and their high luminous efficiency.

3.3.3.5. Accessories:

a) Electrical: They are the wires, switches, and fuses...

b) Mechanical: They are the complementary elements of the installation; structure, screws,...

3.2 IMPACTS OF THE PV ELECTRIFICATION ON THE HOUSEHOLDERS

The Solar Home System (SHS) is the dominant application of PV in rural areas of developing countries. The SHS option has been disseminated through a variety of market and social policy approaches, which has been analysed in a vast range of literature. Existing studies cover well the enabling conditions for a successful commercialisation or dissemination, but generally do not carry an analysis of the implications on rural development. This section aims to summarise what is known in this field. SHS´s have made their impacts mainly at the household level, which, for analytical purposes, can be roughly divided into impacts that can be quantified economically and in impacts that can more easily be described under the heading "quality of life" or welfare impacts.

A general comment on the SHS performance is that they generally provide a reliable source of electricity. This reliability offers a guarantee of continuous service, especially when the alternative is grid connection whit frequent supply interruptions or diesel/gasoline/kerosene options that depend on unreliable access to fuel, situation that occur all too frequently in rural areas. This reliability is generally highly appreciated by SHS users but further research is needed to assess the intrinsic (economic) value in terms of the rural development process.

Apart from trying to evaluate the impact of SHS "from the outside" and trying to objectively do cost-benefit analysis, rural inhabitants do their own cost-benefit analysis when they make a decision to buy a SHS. The number of SHS´s installed is therefore an indication of end-users cost benefits analysis. As a derivative of this, studies into the "willingness to pay" can be used as a proxy of such cost-benefit analysis. For instance, studies on the PV market in Kenya, where most of SHS´s installed are sold by commercial companies, show that 50,000 – 70,000 SHS have been installed, more than 90 percent by cash sales and that when grid extension is not a realistic option, 70 percent of the PV system owners would be willing to spend an average of US$390 for expanding the power rating of their SHS (Van der Plas, Hankins, 1997). Other SHS project experience report that SHS users are willing to pay double their traditional monthly spending to obtain the high quality lighting service.

3.2.1 Impact of SHS on households economics

In the introduction to this section it was said that, for analytical purposes, the impact of SHS could be divided between economic and “welfare” impacts. In reality these impacts cannot be divided so easily; in fact the impact on household productive activities overlaps considerably with the impact on off-farm productive activities.

Many studies conclude that there is little or no evidence of direct economic impact by SHS. Other investigations, however, show that SHS´s also support household economic and income generating activities for some end-users, as indicated in a study in Nepal on a sample of 250 SHS user; 13 percent of the interviewed men and 11 percent of the interviewed women perceived an increase in the income generating activities due to the introduction of SHS (DANINA,1999). These activities most often include sewing, basket weaving and other small artisanal activities. Several other examples exist, but there seems to be a lack of research devoted to analysing this home economics sector.

The evaluation of surplus time due to time savings and prolonged hours of light offers another indicator of the (potential) impact that SHS´s have on income generation. As for surplus time the referred Nepal study indicates that 93 percent of respondents realised of over 1,5 hours per day. Other project reports also mention the effect of prolonged hours of light, ranging from one to two hours a day. This “surplus time” is not necessarily dedicated to productive activities, as field observations record also an increase in activities such as TV watching, homework, socialising and reading. Other (often female) activities include more time for household chores, attention to the children and homework; activities that neither are generally nor called productive, but not less valuable. “Surplus time” is therefore an easily quantifiable impact indicator and can easily be linked with the (potential) impact on generating activities.

An interesting trend in this context is that the average size of SHS´s purchased in the developing world is growing, as indicated in interviews with representatives of the PV industry. Larger systems should introduce “excess power” beyond lighting and audiovisuals. If this trend is confirmed and supported by decreasing PV systems price, there could be a higher potential for impacts on households economics. There are, for instance, some examples from projects being implemented in China where the installation of larger PV systems (100 – 300 Wp per family) and PV/wind hybrids led to an increase in productive uses. The monitoring results show that at lest 50 percent of end-users use home appliances for time and labour savings and a typical domestic appliance, the washing machine (with cold water) is introduced not only as washer for laundry but as an effective centrifuge machine to separate butter from milk with considerable time saving gains. Another more widespread example is the introduction of simple electric sewing machines; their usual energy requirement is about 50-75 Wh/day for a sewing machine of 80W power rating. These applications can easily be powered by slightly increasing the size of PV systems for lighting and radio/TV (the marginal cost of 10-20 Wp extra power are low) and cannot only save time but also create more productive tailors.

It is worth mentioning that another rudimental indicator is sometimes used in SHS impact analyses which measures at least a portion of the economic impact related to the savings on energy expenditures such as kerosene, butane, gas and candles. Savings can be considerable; reported savings in Kenya amount to US$10 per month. Most Kenyan households initially invest in small 10-12 Wp panels and in these cases payback periods are as low as 1.5 to 2 years. For larger PV systems, households have shown to be willing to pay several times their monthly energy expenditures for the increased service.

Another important effect of SHS diffusion is the local employment related to the technology transfer and commercialisation of SHSs. The dispersed markets for SHSs lead to the creation of decentralised, local support infrastructure and therefore it is argued that SHS installations generally stimulate rural employment more than the conventional grid extensions.

3.2.2 Welfare impacts of SHS

The following paragraphs summarise information on the (potential) impact of SHS on social welfare, collected through the survey and through the review of literature. A distinction is made between the impacts of the two main services provided, lighting and audiovisuals.

3.2.2.1. Social Welfare Impacts of Lighting Service

Studies on SHS introduction usually mention that there is a general effect related to the provision of basic lighting service in terms of improvement of quality of life at the household level. Studies indicate that the solar systems have an impact on the household quality of life. The quality of lighting output coming from well-designed SHS is much higher than he lighting from kerosene lamps- 400 lumens for a 8W high efficiency solar lamp vs. 60 lumens from a kerosene lamp. The linkage between provision of quality lighting and households increase in social welfare can be summarise in the following effects;

- Extended housework schedule
- Time an labour savings
- Increased reliability and convenience energy use
- Decrease in indoor pollution
- Decrease in accidental fire
- Improve health and hygiene
- Improved education
- Increase in leisure time activities

3.2.2.2. Social Welfare Impacts of Audiovisual Service

The use of SHS´s for audiovisual (radio, TV) can bring the benefits of more access to information and entertainment to the rural villages, but negative impacts are also reported in this context. It is argued that TV programmes can create negative impacts in the realm of what could be called “preservation of traditional, cultural values”, TV watching is sometimes said to create expectations about (urban) lifestyles, disenchantment with rural life, especially in the young, and thereby to contribute to rural-urban migration. In the referred study, it was also found that some villagers who were beneficiaries of solar battery charging service in Thailand expressed the concern for the new habit staying up late at night watching TV, with negative impact in terms of decreased amount of time devoted to sleeping.

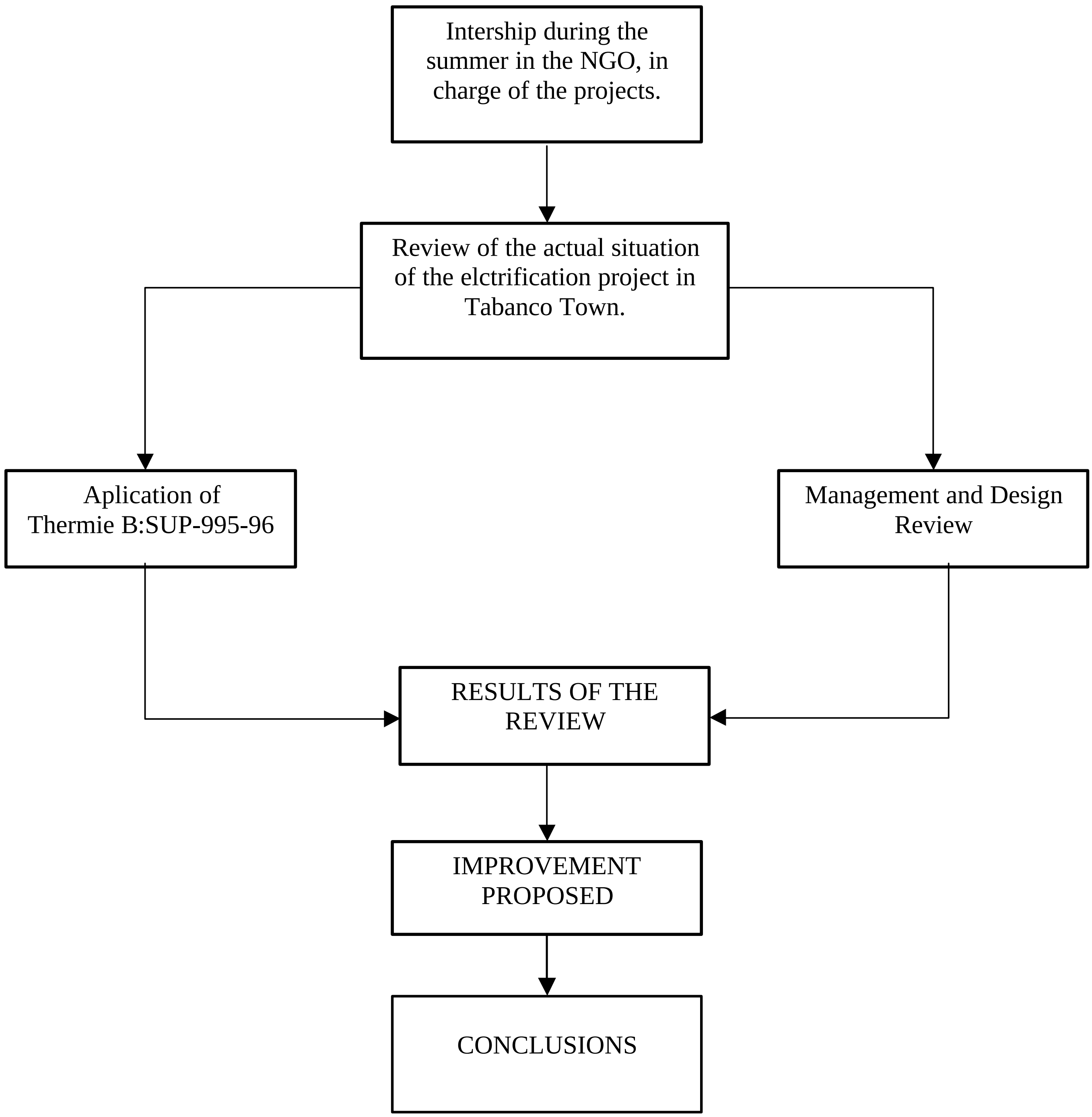
3.2.3 Gender-related aspects of SHS impact

An important aspect of household electrification that has only recently come to the forefront, is the different impact on men and women. The feedback form several studies suggest that there is a higher impact on women and children that on men. The former spend more time at home, performing indoor activities, and thus enjoying more the lighting and audiovisuals services from a typical SHS. It is often noted that the quality lighting helps women to do household work more efficiently and children study after dark. Handcrafts, sewing and embroidery are activities that women carry out at home and that access to electricity translates into productivity gains due to factors such as better work schedule management, higher quality lighting, and extended working hours.

Despite this tendency for higher impact on women, marketing and financing of SHS is generally targeted towards men as the main decision-makers in monetary investments. Training in operation and management is also mostly directed at men, although women are often the ones that spend most time with the systems and are therefore more regularly confronted with failures and imperfection.

4.-DESCRIPTION OF THE METHODOLOGY OF THE STUDY

The following flow chart explains the methodology used for the study of the solar rural electrification project, in this case in Tabanco Town.



5.-RESULTS OF THE REVIEW

5.1.-APLICATION OF THERMIE B: SUP-995-96

5.1.1.-Systems requirements

5.1.1.1. Compulsory

CS1 **Both battery and charge regulator must be protected against over-currents and short-circuit current by the placements of fuses, diodes,etc. In both PV generator and load lines.**

The only protection that exist in the actual project is a fuse of 15 amperes in the charge regulator, the remain elements are without protection with overcurrent and short circuit, to solve this problem is proposed the design of a protection panel

CS2 **PV modules, batteries, charge regulators and ballast must be properly labelled.**

PV module, the battery and the charge regulator are properly labelled;
In the case of the module and the charge regulator are of the label Isofoton and their characteristics are convenient specified. In the case of the battery is from Peru and of the label Record, they are from the automotive sector and their characteristics are also properly labelled.
The element that is not properly labelled is the ballast that in this project two kinds are used, one from the spanish co-operation and the others from the informal market without any kind of label.

5.1.1.2. Recommended

RS1 **The design daily energy consumption value must be selected in the range 120-160 Wh/day.**

The currently project is dimensioned with 160 Wh/day of energy needs, that is under the limits established by the norm.

RS2 **The size of the PV generator should be chosen to ensure that the energy produced during the worst month can, at least, equal the demand of the load.**

This project has been done with mean values, it hasn't been done using the worst month in irradiation means. In the case where the project is located this is not very important because is very near to the Equator line and the variations between summer and winter in solar irradiation means are very small. .

RS3 **The useful capacity of the battery (nominal capacity of discharge multiplied by the maximum depth of discharge) should allow for a three to five day period of autonomy.**

The capacity of the system is; Cu =Cb x DDP = 140 x 0.16 =22.4 Ah, this capacity provides an autonomy of 22.4 / 14.8 = 1,5 days, so it doesn't compliment the norm. This condition is not very important because the irradiation in Tabanco is for sure.

RS4 **In cases where manual tracking is provided, the estimated surplus in collected irradiation should not be considered for sizing purposes.**

All the modules are installed fixed.

RS5 With an irradiance of 800W/m^2, the maximum power voltage of the PV generator at the annual maximum ambient temperature of the site should be 14.5 y 15 V.

The maximum power voltage at 1000 W/m^2 is 17,4 V., there are no data available for this study.

RS6 All protection fuses should be of a widely available type (car fuses, for example.

The only fuse that is used is the charge regulator one, it is specifically designed for the regulator. There are some spare fuses that are managed by the Women Group. These fuses come from the Spanish co-operation and impossible to get in the local market.

Copper wires are widely used and each wire has a "popular" capacity. This is absolutely forgive by the engineers, but because the lack of stock or emergency situations, the use is quite common.

It is proposed the search in the local market of a feasible fuse.

5.1.1.3. Suggested

SU1 **In regions with frequent storms, manual isolation of both the positive and negative poles must be installed on the PV side, so that the PV generator can be isolated when there is a risk if lightning strikes.**

The area in which the project is located doesn't have frequent storms so it won't be necessary to isolate the PV generator.

5.1.2. PV Generator Requirements.

5.1.2.1 Compulsory.

None

5.1.2.2 Recommended.

RG1 PV modules certified according to the international standard IEC-61215 or to the national standard of PV modules used by the relevant country.

PV modules used in this project are ISOFOTON (50 Wp), that complement the international standard IEC-61215.

5.1.2.3 Suggested

None.

5.1.3. Support Structure Requirements.

5.1.3.1.Compulsory.

CU1 **Support structures should be able to resist, at least, 10 years of outdoor exposure without appreciable corrosion or fatigue.**

The support structure is formed of a inoxidable steal tube embedded in a concrete block. As part of the project is estimated that the structure will resist without problems the corrosion, but a layer of protective paint is quite expensive.

CU2 **In the case of frame PV modules, only stainless steel fasteners (screws, nut, tings,etc.) may be used for attaching to the support.**

This condition is not complimented, but its compliment is not very expensive but it increases clearly its quality.

CU3 **In the case where manual tracking (2 or 3 positions per day, moving from East to West) is used, all of its features must meet the support structure requirements specified here.**

There isn't manual tracking in this project.

5.1.3.2. Recommended.

RU1 **Support structures must be withstands winds of 120 Km/h.**

Structures can withstand this speed, because they had already withstood meteorological conditions with speeds bigger than 120 Km/h.

RU2 **Tilt angle should be selected to optimise the energy collection during the worst month, i.e., the month with the lowest ratio of monthly mean daily irradiation to the monthly mean daily irradiation to the monthly mean daily load. Generally, the following formula can be used**

Tilt (º)=max(/Φ/+10º ; 10º

Where Φ is the latitude of the installation.

In this project the latitude 5º 10´, then the value of inclination recommended Φ =15º, that is the value used in the actual project.

RU3 **Static support structures are generally preferable to tracking ones.**

All the support structures in this project are static.

RU4 **Pedestal and wall mounting are preferable to roof mountings for PV generators.**

All the mountings in this project are of prefabric pedestal.

5.1.3.3. Suggested

SU1 **Pedestal and wall mountings are preferable to roof mountings for PV generators.**

All the mountings in this project are of prefabric pedestal.

SU2 **Manual tracking (2 or 3 positions per day, moving from East to West) can be used. In this case, the estimated increase in collected irradiation should be not considered for sizing purposes.**

There aren't manual tracking modules in this project.

5.1.4. Battery Requirements

5.1.4.1. Compulsory

CB1 The thickness of each plate must exceed 2mm.

The batteries used come from the automotive sector so they are prepared for deep instantaneous and not prepared for small discharges during long time, so it compliments perfectly the specification.

CB2 The amount of electrolyte must exceed 1.15 l per 100 Ah of 20-hour nominal capacity and per cell.

There are not values of 20 hours nominal capacity available.

CB3 The 20-hours nominal capacity in Ah (measured at 20ºC and until a voltage of 1.8 V/cell) should not exceed CR times the PV generator shorcicuit current in amps (measured at Standard Test Conditions). For each type of battery, CR values are proposed in the table bellow.

Battery type	CR Compulsory	CR Recommended
Tubular	20	15
SLI:		
Classical	40	30
Modified	40	35
Low-maintenance	40	30

The battery used in this project is a classical automotive, so its correspondent value is CR 40 compulsory and CR 30 recommended.

The 20-hours of nominal capacity, C_b(20-horas), is the capacity value with a discharge of 20 hours. There are not values of 20 hours nominal capacity, but it should be:

- C_b(20-hours) ≤ 40x 3,27 = 130,8 Ah
- C_b(20-hours) ≤ 30x 3,27 = 98,1 Ah

It is recommended to the Installer Company to get these data, and implement modification from they in case of needed.

CB4 The maximum depth of discharge, PD_{max}, (referred to the 20-hours nominal battery capacity) should not exceed the values proposed in the table bellow.

Battery type	PD_{max}, Compulsory	PD_{max},Recommended
Tubular	80	70
SLI:		
Classical	50	30
Modified	60	40
Low maintenance	30	20

The battery used in this project is a classical automotive, so they must have the maximum depth of discharge PD_{max}, of 50% compulsory and 30% recommended, in this project PD_{max} is calculated as 16%. There are not values of 20 hours nominal capacity.

CB5 Provision must be made to ensure that the capacity of the delivered batteries is not bellow the 5% of the nominal value.

Nowadays there isn't any control of that kind, the installer company TRILUX should be done it.

CB6 The self-discharge rate of the batteries, at 25ºC, must not exceed 6% of their rated capacity per month.

Nowadays there isn't any control of that kind, the installer company TRILUX should be done it.

5.1.4.2 Recommended

RB1 **The separator must be made if microporous polythene.**

This condition is complimented.

RB2 **The useful capacity of the battery, C_n, (20 hours of nominal capacity, as define above, multiplied by the depth of discharge) should allow for a three to five day period of autonomy.**

There are not values of 20 hours nominal capacity. But the battery is oversized enough to compliment the period of autonomy proposed in the norm.

RB3 **The cycle life of the battery (i.e., before its residual capacity drops bellow 80% of its nominal capacity) at 20ºC, must exceed a certain number of cycles, NOC, when discharged down to a depth of discharge of 50%. For each type of battery, a NOC value is given in the table bellow:**

Battery type	NOC
Tubular	600
SLI:	
Classical	200
Modified	200
Low maintenance	300

The battery used in this project is a classical automotive, so it has a NOC value of 200 cycles. There aren't any study done, so a relevant study will be proposed.

5.1.4.3 Suggested

SB1 The density of the electrolyte must not exceed 1.25 g/l.

The electrolyte of the batteries used in this project have a density of diluted acid sulphuric of 1.20 g/l .With the correct maintenance and frequent refillment of the battery with distilled water there should be any problem at all.

5.1.5. Charge Regulator Requirements.

5.1.5.1 Compulsory.

CR1 Deep discharge protection must be included.

The Deep Discharge is a process in which the battery is under an extreme usage. Thereby, the customer uses more energy than the recommended. The Deep Discharge is avoided with the correct value of Load-disconnection in the charge regulator.

CR2 "Load-disconnection" voltages should correspond to the maximum depth of discharge values defined in CB4, when the discharge current, in amps, is equal to the daily load consumption, in amp-hours, divided by 5.

There are not values of 20 hours nominal capacity available.

CR3 "Load-disconnection", "load-reconnection" and "warning" voltages should be accurate to within ±1% (±20mV/cell, or ±120mV/battery of 12V) and remain constant over the full range of possible ambient temperatures.

From the results got in the Annex I we can conclude;

-"Load-disconnection" voltage; 80% compliment the norm.

-"Load-reconnection" voltage; 90% compliment the norm.

-"Warning" voltage; 80% compliment the norm.

The results are quite good, so the charge regulator makes right its function and its right calibrated.

CR4 End-of-charge voltage should lie in the range from 2,3 to 2,4 V/cell, at 25ºC.

From the results of the Annex I we can conclude:

-This specification of the end-of-charge voltage is only complimented by 20% of the installations, this is because the end-of-charge voltage isn't designed to compliment this specification.

CR5 In the case of two steps controllers, the reposition voltage should lie in the range from 2,15 to 2,2 C/cell, at 25ºC.

In this project there aren't two steps controllers.

CR6 A temperature correction of –4 to –5 mV/ºC.cell should be applied to the end-of-charge and reposition voltage ranges mentioned above. (This specification must be C(compulsory) only if ambient (indoor) temperatures around the controller are expected to vary significantly during the year, say by more than (±10ºC). Otherwise, temperature compensation circuitry is not really needed)

The area of the project keeps the temperature between the limits imposed by the norm, so, the temperature correction and the temperature compensation circuit aren't necessary.

CR7 End-of-charge and reposition voltages should be accurate to within 1% (±20mV/cell or ±120mV/ 12V battery)

From the results of the Annex I we can conclude:

-End-of-charge voltage; 70% compliment this norm.

-Reposition voltage; 80% compliment this norm.

The results are quite good, so the charge regulator makes right its function and its right calibrated.

CR8 If electro-mechanical relays are used, the reposition of the charge should be delayed between 1 and 5 minutes.

In this project there are not electromechanical relays.

CR9 All the charge regulator terminals should easily accommodate; at least 4 mm^2 section cables.

The charge regulator is designed to compliment this norm.

CR10 Internal voltage drops between the battery and generator terminals of charge regulator must be less than 4% of the nominal voltage (=0.5 V for 12V) in the worst operating conditions, i.e., with all the loads "off" and the maximum current from the PV generator.

From the results of the Annex I we can conclude:
Internal voltage drops between the battery and generator terminals compliment in 100% of the cases this norm.

CR11 Internal voltage drops between the battery and load terminals of charge regulator must be less than 4% of the nominal voltage (=0.5 V for 12V) in the worst operating conditions, i.e., with all the loads "on" and the no current from the PV generator.

From the results of the Annex I we can conclude:
Internal voltage drops between the battery and generator terminals compliment in 80% of the cases this norm.

CR12 Controlled overcharging of "low-maintenance" SLI batteries must be avoided.

Batteries used in this project aren't "low-maintenance" batteries, because they require a constant control of the water level.

CR13 Reverse current leakage protection must be provided.

In the design of a charge regulator of the parallel or shunt type, it's included the protection. This protection is done by a diode that doesn't allow that the battery current return trough the controller or PV panel.

CR14 The charge regulator must be able to resist any possible "non-battery" operating condition, when with the PV generator is operating at Standard Test Conditions and with any allowed load.

There aren't experimental data, but the system is oversized enough so all the components can stand this condition without any damage.

CR15 The charge regulator must also protect the load in any possible "non-battery" condition, as defined above, by limiting the output voltage to a maximum of 1.3 times the nominal value. (Full interruption of output voltage is also allowed).

There aren't experimental data, but the system is oversized enough so all the components can stand this condition without any damage.

CR16 The charge regulator must resist without damage the operating conditions defined by: ambient temperature of 45ºC, charging current 25% greater than the short circuit current of the PV generator at Standard Test Conditions, and discharging current of 25% greater then that corresponding to the full load "on" at the nominal operating voltage.

There aren't experimental data, but the system is oversized enough so all the components can stand this condition without any damage.

CR17 Charge regulator boxes must provide protection to at least IP 32, according to IEC 529 o DIN 40050.

The charge regulator used in this project is labelled ISOFOTON with high quality and fiability products.

CR18 The charge regulator must not produce radio frequency interference in any operation condition.

It hasn't been detected any radio frequency interference.

CR19 The parasitic electrical consumption of the charge regulator in normal operation (i.e., PV generator and load lines "on" and push-button (if existing) not pressed) mustn't exceed 15 mA.

Compliment this characteristic because in the case of the controller used in this project, this current has a value of 7mA.

CR20 If the load can be used without any restriction, then the battery state of charge is indicated by a green signal.

Compliment this condition.

CR21 If the battery has been disconnected from the load because its state of charge is too low, then this is indicated by a red signal.

Compliment this condition.

5.1.5.2 Recommended.

RR1 "Load-reconnection" voltage should be 0.08 V/cell (or 0.5 V per 12V) higher than the "load-disconnection" voltage.

From the results of the Annex I we can conclude:

-The difference between the "Load-reconnection" voltage and "load-disconnection" voltage compliment the norm in the 90% of the cases.

RR2 Warning facilities must be included.

The charge controller has a colour code to identify the battery state:

-Green; free consume.

-Yellow; attention, few energy remaining.

-Red; it is not possible to consume more, the charge regulator is going to cut the supply.

RR3 "Warning" voltage should be selected such that the warning signal is activated 30 minutes before "load disconnect" occurs, assuming all the loads are "on".

From the results of the Annex I we can conclude:

In 80% of the cases this time is complimented, we can consider that this is a good percentage.

RR4 Disconnection of the load should be delayed for between 3 and 30 seconds after the load disconnection voltage has been reached.

From the results of the Annex I we can conclude:

In 80% of the cases this time is complimented, we can consider that this is a good percentage.

RR5 **End-of-charge voltage should correspond to a recharge factor between 0.95 and 1, at a constant current equal to the short-circuit current of the PV generator at STC.**

This information is not available.

RR6 **The charge regulator should allow battery charging from the PV module for any voltage greater than 1.5 V/cell.**

The charge regulator allows the charge of the battery from 10.6 V, so it doesn't allow the charge from 9 V, as the norm requires.

RR7 **Charge regulator boxes must provide protection to at least IP 32, according to IEC 529 o DIN 40050.**

The charge regulator used in this project is labelled ISOFOTON with high quality and fiability products.

RR8 **The charge regulator should be protected against reversed polarity in both PV generator and battery lines. Diode-fuse or other arrangements can be used**

The charge regulator includes in its design.

RR9 **The charge regulator should be protected against induced over-voltages by means of a 1000 W, or greater, transient voltage superior inserted between both (+ and -) poles, at the PV generator input .**

The charge regulator includes in its design.

RR10 **The charge regulator should be protected against induced over-voltages by means of a 1000 W, or greater, transient voltage superior inserted between both (+ and -) poles, at the load output.**

The charge controller compliments this part of the norm.

RR11 The parasitic electrical comsuption of the charge regulator in normal operation (i.e., PV generator and load lines "on" and push-button (if existing) not pressed) mustn't exceed 15 mA.

It doesn't compliment this characteristic because in the case of the controller used in this project, this current has a value of 7mA

RR12 If there is a risk that the battery will soon be disconnected from the load, then this is indicated by a yellow signal.

The condition is complimented.

5.1.5.3. Suggested

SR1 The charge regulator can include an independent battery voltage sensor line.

There are available some charge controllers that include a voltmeter, for example; I-15 MA de ISOFOTON. The reason why they aren't use is because they are very expensive.

SR2 Controlled overcharging should be done at a constant voltage of 2.5 V/cell. Overcharging should occur after each deep-discharge and/or at 14-day intervals. Overcharging should last between 1 and 5 hours.

There aren't the infrastructure needed for that action.

SR3 If should be possible for controlled overcharging to be manually switched off.

The controlled overcharging is not going to be done.

SR4 The upper and lower controlled overcharge voltages should respectively be 2.5 and 2.25 V/cell.

The controlled overcharging is not going to be done.

5.1.6. Requirements of the lamps.

The ballast and the fluorescent can't be today evaluated under this norm because:

-The vast part of the ballast comes from old reformed ones, and their quality is not very good.

-Lamps are now the main problem of the ongoing of the systems, and there are more lamps buried that previously expected.

The actual decision of the engineering department of Piura University and the installer company TRILUX is the design and change of the lamps. The compliment of the norm will be a proposed improvement for the system.

5.1.7. Wiring Requirements.

5.1.7.1. Compulsory.

CW1 **Notwithstanding the above maximum requirements, the minimum acceptable cross-section of the wire in each of the following subcircuits is as follows:**

- **From PV module to charge regulator** **2.5 mm^2**

  It is use a wire of AGW 12 that correspond with one of 3.3 mm^2 so it compliments the norm.

- **From charge regulator to battery** **4 mm^2**

  It is use a wire of AGW 12 that correspond with one of 3.3 mm^2 so it doesn't compliment the norm, it must be use a wire of AGW 10 that correspond with one of 5.3 mm^2 that compliments the norm.

CW2 **External cables must be specifically adapted to outdoor exposure according to the international standard IEC 60811 or to the national standard for cables used by the relevant country.**

Wires here used to outdoor come from the local market and they aren't under any quality supervision. .

CW3 **All cable terminals must allow for a secure and mechanically strong electrical connection. They must have low electrical resistance; leading to voltages losses less than 0.5% of the nominal voltage. This applies for each individual terminal at the maximum current condition.**

The connections used in this project are quite bad, being unsafe and low quality. It is recommended to use borne that will give a secure and mechanically strong electrical connection.

CW4 **Cable terminals should not be prone to corrosion arising from junctions or dissimilar metals.**

Wires used in this project are of copper covered with plastic, terminals aren't protected against corrosion, and so correspondent protection is proposed.

CW5 **Cable that is > 4 mm^2 must be fitted with copper terminals. Cables ends that are <2.5 mm^2 may be twisted and dipped in tin to secure a proper connection.**

In this project there aren't wires of a section bigger than 4 mm^2 so this appreciation won't be take into consideration. The wires used in this project with section smaller than 2.5 mm^2 are the ones that go from the regulator to the different charges. These ones aren't twisted and dipped in tin to secure proper connection.

CW6 **Fusses must be selected so that the maximum operating current will range from to 50% to 80% of the rated capacity of the fuse.**

The operating current of the installation is 6 Amp that means 40% of capacity indicated in the fuse. It would be correct to decrease the capacity of the fuse to the better protection of the elements of the system.

CW7 **Plug/socket combinations must be protected from reversing the polarity of the voltage supplied to the appliances**

In this project there aren't any precaution to avoid this possible problem.

5.1.7.2. Recommended

RW1 All wiring should be colour coded and/or labelled.

The wires that go to the different charges are white and haven't any label. The wires used to connect the PV panel with the charge controller are vulcanised wires with to wires inside them, one red and other black corresponding to the polarities.

RW2 Fuses should be preferably installed in the positive line.

In this project there is only one fuse that is located in the positive line.

RW3 Switches should be specially adapted for DC

The switches used in this project are standard ones, easily available in the local market. They work right under DC conditions.

RW4 If AC switches are permitted, the nominal AC current rating should exceed the maximum DC current to be switched by at least 200%

AC switches are not used because the project is totally in DC current.

5.1.7.3. Suggested

None

5.1.8. Installation Requirements.

5.1.8.1. Compulsory.

CI1 **The battery must be located in a well-ventilated space with restricted access.**

Normally the battery is located in a place that every member of the family can access, the problem is the lack of the space in these rural homes.

CI2 **Provisions must be taken to avoid accidental short circuit if the battery terminals.**

In many cases, the battery is another element of the house over which from clothes to food is placed. The battery is installed without any protection, it is recommendable to cover it.

CI3 **The PV generator must be entirely free of shadows during, at least, 8 hours per day, centred noon, all through the year.**

In this project there isn't this problem because it's placed in the middle of the dessert.

CI4 **All the necessary installation materials (screws, connectors, fitting, etc.) must be included into the SHS supply.**

The installation of this project it's done by a company called TRILUX. They are the responsible to provide all the material.

CI5 **Support structures must be mounted to allow easy access for PV module cleaning and connection boxes inspection.**

The cleaning of the module is very easy and the owner does it. The connection box is located in an easy access place..

CI6 **Support structures must be mounted such that their resistance to corrosion, fatigue and wind are preserved.**

TRILUX are the responsible to provide this service that must be required by the project manager.

CI7 **If roof mounting is permitted, then a gap of at least 5 cm must be provided between the PV modules and the roof for the circulation of cooling air.**

In this project there aren't roof-mounted modules.

CI8 **If roof mounting is permitted, support structures should not be fixed onto roofing sheets, but to a roof beam or an integral part of the structure of the house.**

In this project there aren't roof-mounted modules.

CI9 **Charge regulators and lamps must be provided with suitable mounting brackets/fixings (installation must be relatively simple)**

TRILUX are the responsible to provide this service that must be required by the project manager.

CI10 **Charge regulators and lamps must be designed in such a way that access to fuses and wiring terminals is relatively easy.**

The charge regulator is labelled ISOFOTON, the fuse is easy visible and the wiring terminals are designed to have a very easy usage.

CI11 Tooling requirements must be minimised (avoid different bolt/screw sizes, etc.)

TRILUX are the responsible to provide this service that must be required by the project manager.

CI12 Cables must be stapled into the wall at appropriate intervals to secure them both horizontally and vertically if exposed, otherwise they must be buried or recessed and plastered into walls.

All the intervals of the installation are either horizontal or vertical. TRILUX do it as a basic in their work.

CI13 Cables must be secured to support structures or walls to fully avoid mechanical forces on other elements (connection boxes, ballast, switches,etc)

All cables are fixed to the walls or support structures, both of "caña de guayaquil" that is stable and secures enough.

CI14 Parallel connections of more than two batteries are not permitted.

In this project is only used one battery.

CI15 Parallel connections of different batteries are not permitted.

In this project is only used one battery.

CI16 Parallel connection of old and new batteries is not permitted.

In this project is only used one battery.

5.1.8.2. Recommended.

RI1 The battery should be placed in an easily accessible location (Note: access should normally be restricted, for example means of a locked door)

Normally the battery is located in a place that every member of the family can access, the problem is the lack of the space in these rural homes.

RI2 Cables should be kept out of reach of small children.

This is quite difficult because houses are small and with out restricted access areas.
The cables that children can access are; battery, charge regulator, and the switch ones.

RI3 All cables lay should be horizontal or vertical never oblique.

All the intervals of the installation are either horizontal or vertical. TRILUX do it as a basic in their work.

5.1.8.3. Suggested

None

5.2.- MANAGEMENT AND DESIGN REVIEW.

5.2.1. Previous Data

5.2.1.1. Name;

Rural electrification of Tabanco town.

5.2.1.2. Located;

El Tallán District, Piura area, Grau region, Perú

5.2.1.3. Solar Irradiation;

5.5 Kwh/m2.day

5.2.1.4. Access;

Easy, at one side of the North Panamericana Road, Chiclayo direction.

5.2.1.5.Town;

Nº of in habitants; 1073

Nº of families; 174

5.2.2. Life

5.2.2.1. Cultural and productive habits

The families of Tabanco Town work basically in the next activities:
-40 % Agriculture, beside the Piura river.
-30 % works in the civil construction, as no qualified workers.
-20 % Part time workers.
-10 % Commerce and Transport.
The resting day is on sunday and most of the people are catholic.

5.2.2.2. Social Organisation

There is a communal place where some different meeting are done and where is centralised the small cultural activity of the area (video films, talks, etc...). The water is obtained by means of a solar energy pump, the access to the water is done by an strictly order and till the daily water is finish. The community owns the pump.

5.2.3. Needs that the project wants to satisfy

5.2.3.1. Definition

Supply to the inhabitants of the Tabanco Town of electrical energy by means of solar photovoltaic systems. The main reason is to finish the use of kerosene lamps that hurt the eyes of the children at school age. Apart of that to provide an energy resource for the radio and black and white television.

5.2.4. Previous Technological System

5.2.4.1. Hardware:

-Energy Resource**;**

The energy resource used before was the kerosene lamps for illumination and rechargeable batteries for radio and television.

-Consumes;

As an average, each house have 2 lamps that cost 4 pounds each one and that are necessary to renovate every 4 or 5 years. The total consume of kerosene is 3 litres a week, that cost 0.25 pounds/litre.

-Characteristics of the service**;**

There are different services:

- Kerosene; It is widely used and is very easy to get, there is a seller that provides it.
- Battery; The batteries are recharged in the city, this means from three days to one week without the battery. There is a house delivery service.

-Maintenance and Spare parts**;**

Both battery and kerosene lamp are widely used, so the spare parts are very easy to get. The maintenance is very easy and every owner is in charge of it.

-Initial and Frequent Costs**;**

The costs are:

Lamp; Each lamp cost 4 pounds.

Battery; It cost is between 15 and 25 pounds.

The lamp has a normal life, without taking into consideration the possible accidents, of from four to five years and in the case of the battery the average life is from six to seven years. The battery is recharged once every two weeks with a cost, including the transport of one pound per recharge. The consume of kerosene is three litres every week, being 0.25 the litre, that cost every week 0.75 pound to the user.

-Other services related with the energy resources**;**

For the radio it is used normal small batteries that is a serious environmental problem.

5.2.4.2. Software:

-Rules of Usage**;**

Each owner is the responsible of his energy capacity management, most of the time the energy is used if there are cash available.

-Responsibilities**;**

Personal.

-Effort of the customers**;**

The money needed for the illumination and for the battery is more than the 35% of the family incomes.

-Affected activities**:**

Social and Cultural; Prior to the rural electrification with solar energy of the communal centre (concurrent to this project), the meetings were done because community matters or to communal works. Because the new availability of a communal video a colour television the reasons for meetings have increased, thereby the quality of life has also increased.

Productive; The use of kerosene affects mainly to two activities;

-Children study.

-Women night work

5.2.4.3. Orgware:

-General organisation**;**

-Local merchant of kerosene; buys the kerosene (lots of approximately 200 litres) with a price of 0.2 pounds/litre and he sells in bottles from 1 to 4 litres, with a price of 0.25 pounds/litre. The incomes from this activity are around 25 pounds.

-Battery recharger; He charges for every recharge 0.6 pounds getting 0.4 pounds of profit in each recharge. As an average he recharge 50 every month, so he gets an income of 20 pounds because this activity.

-Agents related with the commercialisation**;**

They are;

Batteries; The batteries are bought in the local market and most of them are second hand ones.

Lamps; they are available in every commerce.

-Agents related with the maintenance**;**

The maintenance is personal.

-Decision procedures;

Personal.

-Procedure in special events.

As the energy use is completely personal, in case of a catastrophe there is no place to ask for compensation.

5.2.5. Photovoltaic experience and expectatives.

5.2.5.1. External References.

The nearest area that has access to the electrical grid is the Piura city, there the consume is of a big variety depending in how wealthy is the area. There are problems with the payments to the electrical company because with the kerosene lamps you use energy if you have it but when they are connected to the grid the control of the consume is very difficult.

5.2.5.2. Photovoltaic experience in the area.

The electromechanical engineering department of the University of Piura in collaboration with the local NGO Mirhas Peru has done some projects in the region but not in this area. Thereby, they spent almost a year doing a social-cultural campaign, showing the system to the future users. These actions are one of the main keys to the success of the project.

5.2.5.3. Technical capability of the local people.

There are some young men in the area with enough electricity knowledge that with some training could be in charge in the future of the maintenance of the systems, so the disappearance of the external people related with the project will be easily and more effective in order to finally obtain an sustainable project.

5.2.6. Resources of the owners.

5.2.6.1. Economical incomes.

The mean economical incomes of the inhabitants of Tabanco town are between 20 and 40 pounds monthly. Some families earn extra cash doing handicrafts at night.

5.2.6.2. Economical Expenditures.

The expenditure in energy resources is more than 35% of the monetary incomes. The remaining is used to cover their basic needs.

5.2.7. Technological system proposed.

5.2.7.1. Hardware:

-Estimation of the service and demand of energy;

The mean energy consume projected is;

Equipment	Power (w)	Hours of use (h/day)	Energy (Wh/day)
Lamp	15	2	30
Lamp	10	2	20
Lamp	15	2	30
Tv B/W	15	2	30
Radio	10	5	50
TOTAL	65		160

We can conclude that the electrical energy needs will be 160 Wh/day, and the power of the electrical installation must be of 65W, in case that all the appliances are connected at the same time.

-Photovoltaic system selected**;**

The photovoltaic system proposed was;

-Solar Panel; ISOFOTON (50 Wp)

-Battery; RECORD RT-23HT

-Charge Controller; ISOFOTON I-15 DC

-Relevant dimensions**;**

The relevant dimensions are;

-Solar panel; with a power of 50 Wp

-Battery; with a capacity of 140 Ah

The rest of dimensions are in Annex II.

-Initial Cost**;**

From the original budget we get the following data:

-Photovoltaic Panel 50 Wp:	360 pounds
-Charge Controller 15 A:	61,6 pounds
-Lead-acid battery 140 Ah:	96 pounds
-Lamps of 12 Vdc, three each house (two of 15W and one of 10W):	39,6 pounds
-Electrical accessories:	61,6 pounds
-Support structure for the PV panels:	36 pounds

Because its external funding, part of the costs are granted.

There is a fixed price of 540 pounds.

-Maintenance costs**;**

In the project is not included a maintenance cost, this is left in charge of the local NGO Mirhas Peru and the installer company TRILUX. The maintenance is organised in an informal way and has a small efficiency.

-Characteristics of the systems**;**

Consult the Annex II.

5.2.7.2. Software:

-Rules for the use**;**

The system has its owns rules for the use , so it's the responsibility of the owner to know them. The main rule is that the energy that you have available today, if you don't use it you don't save it, you just lose it. The charge controller is the device that will control the use.

-Responsibilities**;**

They are the followings:

-The system will be of the customer when he will pay all of it, if for instance a customer doesn't pay his bills the system could be removed.

-The installer company TRILUX, give one year of insurance for all the components of the system.

-The electromechanical department of the University of Piura has the responsibility of the technical supervision.

-The local NGO Mirhas-Peru has in charge the management of the payments, helped by the Women Group.

-The customer must pay the whole system financed for several years (depending in the economical possibilities of the customer). The value is fixed and paid in Soles (Economically is the weakest point, because due the fragility of the Peruvian economy the Sol can easily have big devaluation and the components of the system are bought in Dollars.

-Contribution of the customers**;**

No contribution is expected, normally they help in the installation process.

-Maintenance procedure**;**

The owner recibe advice and norms, but they aren't neither typified nor regulated. The lack of a maintenance procedure; clear, ordered and specific, is one of the main reason some PV rural electrification fail with the time.

5.2.7.3. Orgware

-General Organisation;

The general organisation in this project is:

-Spanish NGO; They look for funding for the projects, their roll is being the meeting point between the founders and the local organisations that do the project. It is also in charge to supervise the right management of the projects.

-Local NGO Mirhas Peru; It is the local partner, they are in charge of manage the projects. They are comformed of inhabitants of the same development country. Their task is to manage the daily ongoing of the project.

-Electromechanical Engineering department of the Piura University (UDEP); They are in charge of the technical part of the project.

-TRILUX; It is the installer company, it task is to provide all the elements of the installation and also install them.

-Women Association; They are the representants of the customers. They work together with Mirhas-Peru in the economical and social management of the project.

-Agents related with the promotion**;**

The local NGO and the Electro-mechanical department of UDEP.

-Agents related with the commercialisation**;**

The local NGO Mirhas-Peru and the Women Association.

-Agents related with the maintenance**;**

The local NGO Mirhas-Peru ,the installer company TRILUX and the owner.

-Decision procedures**;**

It is as follows:

-The spanisn NGO supervise all the actions and write informs to the funding organisms.

-The local NGO decide with the Women Association about the social and management aspects, they have the freedom to take their own decisions, if they are not against the customer interest.

-The Electro-mechanical Department decide about the technical aspects and supervise the installer company TRILUX.

-Economical administration;

The Women Association with the local NGO Mirhas-Peru are in charge to administrate the money of the project.

-Procedure in special events.

They are classified in:

Robbery; They have no insurance.

Natural disaster; They have no insurance.

5.2.8. Impacts of the project and of the innovation.

5.2.8.1. Hardware

-Economical Benefits**.**

For this we do a comparative study of the expenditures in the first ten years and then in the other next ten.

1)From 0 to 10 years:

1.1.Previous expenditures (Kerosene lamps and battery);

-Kerosene; 0,72 p /week x 50 week/year x 10 years =	360 pounds
-Battery recharge; 0,5 p/wee x 50 wee/year x 10 year =	250 pounds
-Reposition of the lamps; 4 pounds x 2.5 =	10 pounds
-Change of battery; 20 pounds x 2 =	40 pounds
TOTAL	740 pounds

1.2 Expenditures with the PV system;

-Initial Expenditure (the system)=	540 pounds
-Change of Battery; 96 x 1=	96 pounds
-Spare lamps; 39,6 x 4 kits =	158,4 pounds
-Distilled water; 0,4 p/(uni. x month) x 12 months	4,8 pounds
TOTAL	799,2 pounds

SAVINGS = 740-799,2 = **-59,2 pounds**

2)From 10 to 20 years:

2.1.Prior expenditures (kerosene lamps and battery);

-Kerosene; 0,72/week x 50 week/year x 10 years =	360 pounds
-Charge of battery; 0,5 p/we. x 50 we./year x 10 years =	250 pounds
-Reposition of lamps; 4 pounds x 2.5 =	10 pounds
-Change of battery; 20 pounds x 2 =	40 pounds
.TOTAL	740 pounds

2.2 Expenditures with the photovoltaic system;

-Initial expenditure (system)=	0 pounds
-Change of battery; 96 pounds x 2=	192 pounds
-Spare lamps; 39,6 x 4 kits =	158,4 pounds
-Distilled water; 0,4 p/(uni,x month) x 12 months	4,8 pounds
TOTAL	359,2 pounds

SAVINGS = 740-359,2 = **380,8 pounds**

SAVINGS in 20 years= -59,2+380,8 = 321,6 pounds

-No economical Benefits**;**

They are classified in:

-Quality of the illumination; with the new project the quality of the illumination is bigger and not bad at all for the children eyes.

-Feeling of development; The integration of advanced technology, if it is correctly accepted by the habitants, can create an evolution and improvement feeling that can be an incentive to the owners to keep working in their development.

-Comfort; now they don't have to recharge the battery in the city, so now the electricity for the radio and television is available all the days. Also, now they have to buy distilled water instead of kerosene that is easier.

-Hygiene; the environment of the house improves because the new system doesn't generate smoke.

-Additional expenditures;

The additional expenditures that have this project are covered by the incomes coming from the external funding. The only additional expenditure that must do the customers are the ones coming from the operatively of their systems.

-Relative benefits perceived by the customers;

The users realise an improvement in the better quality of the light and an easy availability of the light. They realise the continuity of the energy supply, that means that is not going to be days without supply anymore.

5.2.8.2 Software

-Property Changes;

The property of the equipment is still personal once the total payment is done. In this project was believed that the total pay of the equipment by the international cooperation wasn't a good idea, because when you pay something you take care better of it.

-Changes in the responsibility of the use**;**

The new responsibilities of the users are;
-Knowledge that the energy no used isn't energy saved.
-Learn the colours code for the correct administration of the energy.
-Make the maintenance of the system by themselves.

-Complexity perceived by the users**;**

The users perceive this technology as a complex and unknown one at the beginning. It can be teached the different details of the function of the system)

-The necessity of training;

The training gave today is very few and we can resume as follows;
-Explanation when the system is installed.
-Recommendation that the workers of the local NGO Mirhas-Peru do when they visit the projects.

-Roll of each social group

The Tabanco town is a young establishment in which the different social groups are not clearly defined, there are a slight community feeling.
The main social group is the Women Group, that is very young.

5.2.8.3. Orgware

-Indirect Benefits**;**

When the new technology is deployed, then appear the following indirect benefits;
-Work for the installers of TRILUX
-Work for the local NGO Mirhas-Peru
-Work for the spare merchant.

-Possible affected**;**

The possibles affected are;
-The kerosene and lamps sellers.
-The battery sellers and the batteries rechargers.

-New participants**;**

The new participants are:
-The installer company TRILUX.
-Merchants of electrical accessories and fluorescent.

-Roll of the dignitaries;

The cooperation projects are strongly supported by dignitaries in all the levels.

6.- RESULTS OF THE REVIEW

In this part it is described the conclusions obtained from the study of the rural electrification project by photovoltaic energy of the Tabanco town. Because the two norms used here to evaluate the project, the results are listed together.

From the results of the review some improvements are proposed to get a better management of the future installation.

1.-From the test done to the system we come to the conclusion that there are a significative big part of the users that has an installation of more power than the power that they really need.

2.-The installations of the system have plenty of weak points and there are actions that must be avoid or modified.

3.-The lamps are the weakest points of the system. They must be changed and find another better and more feasible.

7.- IMPROVEMENTS PROPOSED

As result of the study of the actual systems in their different aspects some improvement are proposed that will improve the actual ongoing of the project, becoming more dynamic and easily autosustainable.

The improvements proposed are:

7.1.-Development of a new alternative system of lower power.
7.2.-Improvements, minimum requirements and values of the installation.
7.3.-Aplication of the Thermie SUP-995-96 to the new lamps.

Here is remembered that this project is done for the customers that are inhabitants of rural areas of development countries, so when an improvement or norm is wanted to be deployed it comes with a big social factor.

7.1.-Development of a new alternative system of lower power.

In this part it is describe the whole calculation of the modified alternative system of lower power. This system is designed for the small families that need less energy.

7.1.1. Design criterion.

For the selection of the system for solar electrification, we have to take into consideration the following criterions;

1. Grade of dispersion: to deploy a centralised or decentralised system.
2. Solar resource availability: evaluated depending of the characteristics of the place.
3. Actual and projected energy consumes of the inhabitants.
4. Characteristics of the houses.

From these criterions it will be taken the next considerations:

1.-The grade of dispersion is not very high, and the possibility of a centralised system will be very expensive and difficult to distribute (high electrical loses). So the system selected is an individual one.

An individual system is composed of :

- A solar panel (photovoltaic module)
- A charge controller.
- A battery for the energy storage.
- Lamps.
- Electrical accessories

2.-As there are not very good values in this area, the solar resource has been empirically evaluated. The area is rich in solar resource.

The values are means and taking into consideration that the latitude is 5º;

- Instant average solar irradiation: 720 w/m2
- Total daily solar irradiation: 5.5 Kwh/m2-day
- Number of average solar hours: 12 hours.
- Number of effective hours of sun : 5.5 hours.
- Of 6 days, 4 son sunny and 2 cloudy.

3.-The consumes of electrical energy nowadays are limited because they don't have any fiable resource. So the future consumes are taking into account to satisfy the basics needs.

As an average, this type of families has two main rooms to illuminate, so they will need only two lamps. The lamps will be:

- For the bedroom (3 x 2 m2): 10 W
- For the kitchen (3 x 3 m2): 15 W

Each family has a radio, of different power. 10W are taken as an average.

In the future, if they have a photovoltaic system, people will get a black and white television that works at 12 V of direct current, so it must be taken into account.

The energy consume projected, as an average, will be:

Equipment	Power (W)	Hours (h/day)	Energy (Wh/day)
Lamp(bedroom)	10	2	20
Lamp(kitchen)	15	2	30
Tv W/B	15	2	30
Radio	10	3	30
TOTAL	50		**110**

We can conclude that the needs of electrical energy will be of 95 Wh/day, and the power of the electrical installation must be 65 W, in case that all the different appliances are connected at the same time.

The installation will be of 12 V of direct current, that is the voltage that the battery gives. The lamps, B/W television and the radio can work without problems with this voltage.

4.-The roof are made of "eternit", oriented to random direction, the modules will be located independent with a post-type structure. Oriented 15º to the north.

7.1.2. Calculations.

Nomenclature:

E_u : Energy mean consume (Wh/day) = 110

R_d : Total daily solar irradiation (kW-h/m^2-day) = 5.5

n_b : Efficiency of the battery (%) = 90

E_b : Energy storage in the battery (Wh/day)

C_{bn} : Net capacity of the battery (Ah)

Vcc : Working voltage in direct current (V) = 12

DDP : Depth of discharge (%)

C_b : Commercial capacity of the battery.

n_r : Efficiency of the charge controller.

E_p : Energy supplied by the solar panel.

n_p : Mean conversion efficiency of the solar panel = 10 %

A_p : Area of the photovoltaic panel (m^2)

I_r : Discharge current of the controller (A)

P_p : Peak power of the solar panel (W_p)

7.1.2.1. Calculation of the main parts of the system.

Battery

Calculation of the energy that the battery must storage:

$$E_b = E_u/n_b = 122.22 \text{ Wh/day}$$

The net capacity of the battery in Amperes-hours will be:

$$C_{bn} = E_b/Vcc = 10.18 \text{ Ah/day}$$

Depending in the type of battery, it will be a percentage of admissible discharge DDP, that in this case will be the one that allows a life of four years to the battery, it means a minimum of 1500 cycles of charge and discharge. For the lead-acid battery, that will be recommended in this project, the permissible value is DDP=16%.

Thereby the total commercial capacity of the battery will be:

$$C'_b = C_{bn}/DDP = 63.65 \text{ Ah}$$

This value is correct, if we suppose that everyday will be a good solar irradiation and that every day it is consumed the forecasted energy. Although, it is necessary to take into account that there are sunny and cloudy days.

For the north (latitude 5º) there is a factor of 50% because as an estadistical mean, there are 4 sunny days and 2 cloudy days.

So, there will be a total capacity of the battery of :

$$C_b = C'_b \text{ x } 1.5 = 95.48 \text{ Ah}$$

The best battery that cover this needs is the RECORD 140 Ah, a little bit more expensive than the 100 Ah one but more feasible.

<u>Charge controller</u>

The charge controller has an efficiency of 95%, so the energy that must get the solar panel must be:

$$E_p = (C_{bn} \text{ x } Vcc)/n_r = 128.60 \text{ Wh/day}$$

The power output is 50 W at 12 V DC, that means that the charge controller must works at a minimum current of:

$$I_r = 50/12 = 4.166 \text{ A}$$

Solar panel

The panel must convert Ep = 128.60 Wh of energy through a typical day, where the total solar irradiation is 5.5 Kwh/m^2-día. The necessary area of solar panel is:

$$Ap = Ep/(Rd) \times n_p) = 0.23\ m^2$$

To choose a commercial value, we apply the definition of peak power for photovoltaic solar panels. This value of power is the one that we get when the irradiation is 1000 W/m^2 (approximately at 12 a.m), at the temperature of the cells of 25ºC de cell.
This means that:

- There will be only some effective equivalent hours for which we can say that the solar irradiation is of 1000 w/m^2, it is defined as:

$$HRE = R_d / 1000 = 5.5 \text{ hours.}$$

- We will have to correct the value of the power because the temperature of the solar panel. This correction factor will be 0.75 for this area.

a
So we get:

$$P_p = E_p /(HRE \times f_t) = 31.175\ W_p$$

The panel select to cover this need is the KYOCERA 35 W_p, because of the company ISOFOTON the nearest are ISOFOTON (47 W_p) and ISOFOTON (22 W_p), and none of them is good enough for this installation.

7.1.2.2. Electrical Accessories

In this second part, it will be sized the electrical accessories and security elements of both internal and external installation.

The installation has the following accessories;

- Wire from solar panel – charge controller.
- Wire from charge controller - battery.
- Wire from charge regulator - charges:lights, radio, etc.
- Key of charges control
- Switches
- Radio connections.
- Tv connections.

The wires will be selected in base of the maximum allowed drop of voltage, following the next formula:

$$S = (L \times I)/(58 \times AV)$$

Where:

S : Section of the conductor (mm^2)
L : Total length (m)
I : Intensity of the current (A)
AV : Drop of voltage (V)

Here there is the equivalencies table between S and the commercial calibration of the conductor AWG, in the case of copper conductors.

AWG	6	8	10	12	14	16	18
S (mm2)	13,3	8,4	5,3	3,3	2,1	1,3	0,8

For the analysed case, we have the following wires;

Localisation	**AV (%)**	**L (m)**	**design (A)**	**S (mm2)**	**AWG**
Panel-controller	3	6x2	5	2,87	12

Controller-battery	2	2x2	10	2,87	12
Controller-charges	5	15x2	2,5	2,15	14

Eventually, the parts of the installation will be:

-Solar panel; KYOCERA 35 W_p

-Charge controller; I-8 ISOFOTÓN.

-Battery for the storage; RECORD 100 Ah.

It is estimated that the sell of this equipment to the users can have an approximated price of 2300 "Nuevos Soles", taking into account that the remaining will be paid by the international cooperation.

7.2.-Improvements, minimum requirements and values of the installation.

The installation of the system is done by the installer company TRILUX, this company doesn't compliment any quality requirement. As one of the results of the study of the systems, here is shown a list of basic requirements in the installation procedure.

1.-Elimination of the actual lamps and change them for better ones.

2.-All the wires of the system must be labelled, if possible with colours, indicating their polarity.

3.-Change in the project the wire that goes from the charge controller to the battery for one that correspond to AGW-10.

4.-Planification and design of the future fuses box to obtain a bigger protection against the overcurrents that could affect to the integrity of the components.

5.-Protect the support structure can stand the corrosion by a hot galvanisation based in Zinc, with that the life of the structure will be longer.

6.-There must be done some essays in order to get some values for the better application of the norm THERMIE B: SUP-995-96.

-The value of 20-hours of nominal capacity.

-The value of autodischarge at 25ºC

7.-There must be done the convenient changes, in the following aspects in order to compliment the norm THERMIE B: SUP-995-96:

- The charge regulator must also protect the load in any possible "non-battery" condition, as defined above, by limiting the output voltage to a maximum of 1.3 times the nominal value. (Full interruption of output voltage is also allowed).

- The charge regulator must resist without damage the operating conditions defined by: ambient temperature of 45ºC, charging current 25% greater than the short circuit current of the PV generator at Standard Test Conditions, and discharging current of 25% greater then that corresponding to the full load "on" at the nominal operating voltage.

- End-of-charge voltage should correspond to a recharge factor between 0.95 and 1, at a constant current equal to the short-circuit current of the PV generator at STC.

7.3.-Aplication of Thermie SUP-995-96 to the new lamps

The new ballast and fluorescent lamp system must compliment the norm before being changed.

7.3.1. Compulsory

CL1 Ballast must ensure safe and regulated ignition in the voltage range from -15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V battery).

CL2 Ballast must be protected against destruction when:

- The lamp is removed during operation or the ballast is operated without the lamp.
- The lamp doesn't ignite.
- The supply voltage is reversed-poled.
- The outputs of the electronic ballast are short-circuited.

CL3 Ballast must not produce radio frequency interference.

CL4 Minimum luminous flux for the total ballast and fluorescent lamps system must be 80% of the nominal value.

CL5 Minimum electrical efficiency of the ballast must be 70% in all the range of the operating voltage (-15% to +25% of the nominal voltage).

CL6 Luminous yield for the total ballast and fluorescent lamp system must be at least 25 lum/W.

CL7 The waveform of the current through the fluorescent lamp must be symmetrical in time to within 10% (i.e., 60% / 40% waveform maximum difference in symmetry) over the voltage range of 11 to 12.5 V at an ambient temperature of 25ºC.

CL8 The maximum crest factor (ratio of maximum peak to RMS voltage of the waveform applied to the fluorescent tube) should be less than 2 over the voltage range from 11 to 12.5 at an ambient temperature of 25ºC.

CL9 Electrodes of ballast must never be connected to lighting fixtures.

CL10 Lamp lenses, covers grids, etc. (if used) must be insect proof

CL11 Lamp lenses, cover grids, etc. (if used) must be easily removable by the users for bulb replacement or for cleaning.

CL12 All fluorescent tubes must be of a widely available type.

7.3.2.Recommended.

RL1 The consumption of ballast when they are operated without lamps must be lower than 20% of their nominal power.

RL2 Luminous yield for the total ballast and fluorescent lamp system must be at least 35 lum/W.

RL3 The DC component of the current through the fluorescent lamp should be zero.

RL4 The maximum crest factor (ratio of maximum peak to RMS voltage of the waveform applied to the fluorescent tube) should be less than 1.7 over the voltage range from 11 to 12.5 V at an ambient temperature of 25ºC.

RL5 Means to preheat electrodes are recommended.

RL6 The simultaneous use of both fluorescent and low-power (<2W) incandescent lamps should be allowed, as long as the total design power is not exceed.

7.3.3.Suggested.

SW1 The luminous efficiency could be increased adding reflectors to the bulb mountings.

SW2 Luminous yield for the total ballast and fluorescent lamp system must be at least 50lum/W.

8.- CONCLUSIONS

The application of the improvements suggested to the project will help for a better function and autosustenability of the systems. From the study of the different areas that compose a rural electrification project for developing countries, results the search for the compatibility between the technical and social part. The repercussion of the project is not only to satisfy the electrical needs of the customers, it also gives the feeling of progress.

This study also provides as the knowledge that a installation that seems at the beginning very easy, then in "its" reality gives more problems that the expected at the beginning. This confirms the importance in a good and a serious planification.

Although the power used in the rural areas of developing countries are very small, it is important to remark the energy adaptability depending on the use, due to the financial aspect in this areas is very important.

Eventually, as final conclusion just say that the Solar Home Systems are the solution for the electrification of millions of habitants of the world that don't have electricity, so the globalisation, study and development of the improved system are recommended.

9.- BIBLIOGRAPHY

1. Enrique Alcor Cabreizo, *"Instalaciones solares fotovoltaicas"*, Ed PROGENSA (Promotora General de Estudios), 1995.
2. IES-UPM, GENEC, WIP, ESTI-JRC, *"Universal technical standard for solar home sistems"*, Thermie B SUP 995-96, EC-DGXVII, 1998.
3. Grupo de Apoyo al Sector Rural (Pontificia Universidad Católica del Perú), *"Formulación y elaboración de proyectos de desarrollo"*, Curso Taller , 19-26 de Julio 1999, Lima (Perú).
4. Instituto de Energía Solar (I.E.S.), *"La electrificación rural fotovoltaica en el ámbito de la cooperación"* (Apuntes para un curso a Organizaciones No Gubernamentales, Madrid 1999.
5. D.Mayer, F.Neirac, J.L.Bal, and P.Beutin, *"Sustinable Development of Areas: Decentralized Electrification"*, Applied Solar Energy, Vol 34, No 3, 1998.
6. André Verani, Chad Nielsen and Philip Covell, *"PV Powers rural communities"*, Solar Today May/June 1999.
7. Centro de Energías Renovables (CER), Universidad Nacional de Ingeniería (UNI), *"Gestión y administración de proyectos de electrificación rural con sistemas fotovoltaicos"*, Lima-Perú 1998.
8. Georg Bopp, Hansjörg Gabler, Klaus Preiser, Dirk Uwe Sauer and Heribert Schmidt, *"Energy storage in photovoltaic stand-alone enregy supply systems"*, Progress in Photovoltaics: Research and applications 6, 271-291 (1998).
9. E. Lorenzo, L. Narvarte, K. Preiser, R. Zilles, *"A field experience with automotives batteries in SHS´s"*, Artículo presentado en el "Second World Conference on Photovoltaic Solar Energy Conversión" Viena, 6-10 Julio 1998.
10. E. Lorenzo, *"Aproximación a una metodología para abordar proyectos de electrificación rural fotovoltaica"*, Instituto de Energía Solar Fotovoltaica, Septiembre 1999.