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Modelling Of Photovoltaic Systems for Power Grid Equipped Houses as Partial Lighting System

V.Thiyagarajan, V.Sekar

Abstract— ***This paper is proposed as a guide for PV programme planners during the process of planning and implementing their projects to make sure that they continue on a sustained basis. This paper details four phases of PV programme planning: the preparation of PV programme, programme design, implementation and monitoring/ evaluation. This should also be used once the programme developer has a clear concept for a feasible plans and should be useful to all the decision-makers in the process of developing programme, may be they are host governments in developing countries, PV programme developers and sponsors, PV producers and suppliers, entrepreneurs, or NGOs. This Paper is deals with preparation for PV programmes, including needs assessment, stakeholder consultation, social context analysis, supply options and national policy considerations and Design of PV programmes, including establishment of goals, delivery modes, timelines, and logistics and quality assurance. A number of methodologies have been developed over the years with the aim of improving programme design and implementation. This paper is intended to highlight the issues related to a rural energy programmes in developing countries rather than providing an in-depth step by step methodology to standard programmed design, planning and implementation. Though the focus of this paper is on PV technologies, much of the discussion will apply to other rural decentralized energy systems. Solar-based electricity for our houses is essential nowadays as the monthly power bills are escalating regularly. Also, the whole world is now facing the challenge 'global warming'. By using eco friendly and green technologies, we would help reduce global warming and help climate change mitigation. Integrated LED modules and other DC operated Electrical equipment conserve energy as they are energy-efficient, possess long-life and require less maintenance. Mini PV powered structure has been designed, analysed and tested in power grid equipped house as a partial lighting system with cost analysis.***

Keywords- Developing countries, PV, Solar Home Systems [SHS], programme design, planning, implementation, deployment.

I. INTRODUCTION

Photovoltaic technology (PV) can supply reliable, relatively cost-effective electricity for basic needs in remote and developing areas. Photovoltaic can be used to better the lives of people in many ways including supplying clean electricity to light homes or schools, powering small businesses and pumping water for domestic and agriculture as well. Using the natural resource of sunlight, the lives of hundreds of thousands of people can be improved in ways that can range from local to upper in scale, depending on the size of the programme and resources available to carry it out.

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V.Thiyagarajan, Ph.D Research Scholar, CMJ University, Shillong, Meghalaya, India.

V.Sekar, Principal, Dhanalakshmi Srinivasan Institute of Technology, Tamilnadu, India.

Poor design is often the root cause of unsuccessful programme or project implementation. In order for a PV programme to be successful, it needs to be planned carefully. However it is important to know that there can never be a blue print for designing programmes. In planning for PV programmes, decision-makers must carefully weigh the costs and potential social, personal, and national benefits that will accumulate from different allocations of resources. In addition, they must put significant effort into assessing the needs to be addressed by a particular PV programme, consulting with stakeholders, analysing potential technological solutions, and then designing a solution that will yield the desired benefits at appropriate costs

Planning for and developing a PV programme is a multi-phase challenge. This paper is designed to give input to those programme developers who are interested in implementing or improving support programmes for the deployment of PV for rural electrification.

II. DIFFERENT PHASES OF PROCESS PLANNING

This paper will lead programme administrators through the process of planning a PV programme, broken down here into the following phases: (1) the preparation phase; (2) the programme design phase (3) the implementation phase; and (4) the monitoring and evaluation of the programme.

Table 1 - Overall Activities Of The Different Phases

Preparation Phase	**Design Phase**
• National policy objectives • Needs Assessment • Stakeholder Consultation and Social Context Analysis • Assessment of capacity Requirements • Identification of technical assistance requirements	• Goals and Objectives • Institutional and Policy Framework • Schedule and Milestones • Logistics • Management and Project team Functions • Training / Capacity Building • Financial Delivery Mechanisms • Technical System Specification and Procurement
• Technical Supply Options and Analysis	• Quality Assurance Aspects • Information management • System • Provision for ongoing • maintenance replacements
Implementation Phase	**Monitoring And Evaluation Phase**
• Quality Control, Management and Evaluation • Information Management System • Capacity Building	• Impact Assessment • Project Evaluation

A. PREPARATION PHASE

The preparation phase of PV programme planning consists of the consideration of the overall policy objectives, a needs assessment, stakeholder consultation, social context analysis, and analysis of technical supply options. Within this phase, the goal or goals of the potential programme are identified.

National and regional policy objectives are taken into consideration, addressing the question whether the programme fits the overall goals and objectives of the state and the society. In addition, this phase includes consideration of the benefits and costs or consequences of the programme – both social and financial. Different technological options available to meet the energy needs must be assessed (e.g. PV, hydro power, etc.) and the best solution for the particular situation needs to be found and then adapted to the particular constraints of the environment. Photovoltaics may not be the best solution for all situations, and often the best solution will be a combination of different technologies. Planning at a high level is weighed down by difficulties. It is difficult to collect reliable data, and equally difficult to know how to use the data once they are obtained. Interviews with stakeholders may or may not yield insight into how stakeholders will react to and benefit from renewable energy technologies. Possible problems or challenges may or may not be identified. Planners must use the best data available, and to the extent that they are able, they must seek stakeholder input and involvement in the programme**.**

1) National Policy Objectives: National policy objectives might vary from emphasis on national infrastructure development to emphasis on hygiene projects, food production, rural electrification. Where possible, local and regional programmes should fit into the national or regional policy objectives of the area in which they will be undertake.

<u>Full employment:</u>

Renewable energy training and workforce infrastructure development to provide employment opportunities like micro- enterprises.

<u>Provision of food:</u>

PV is used to provide water pumping for agriculture purpose and clean drinking water to communities.

<u>Provision of education:</u>

PV to power schools or provide household lighting for study or running educational media (TV, computers, internet)

<u>Achievement of economic equilibrium:</u>

Renewable energy training and infrastructure development to provide employment opportunities empower the local development and expansion of small businesses, provision of sustainable electric or water pumping resource.

<u>Electrification of un-electrified areas:</u>

PV to provide electricity and lighting for rural households and rural applications.

2) Needs Assessment: The needs assessment phase of programme planning must take into account not only why the programme should be undertaken, but who the beneficiaries and other stakeholders are and how they benefit from the programme. A needs assessment should consider both the macro and micro level benefits that an energy project could bring to a population.

<u>Macro Level Benefits:</u>

- Electricity generation in areas not served by electricity grids;
- Increased reliability in areas where grid power is intermittent;
- Limitation or mitigation of the environmental costs of conventional fuels;
- Reduction in greenhouse gas emissions from the production of electricity or the burning of other fuels for lighting.

<u>Micro Level Benefits:</u>

- Water purification and Health care;
- Educational and Research support;
- Communication opportunities;
- Home lighting and small business opportunities;

3) Assessment of capacity building requirements: The next step is to identify where capacity needs to be built and knowledge increased within each stakeholder organisation. Needs should be assessed, in the following stakeholder organisations:

- Relevant Government ministries
- Implementing agency Financial sector
- Installation contractors
- Local industry, small businesses
- End-users

The type of capacity building activities that could be required include developing the skills to undertake the following activities: awareness raising; evaluation and selection of technology options; preparation of business plans; installation, operation and maintenance; financial analysis; project finance; product development; establishment of community based utilities; setting tariff structures and accounting procedures.

4) Identification technical assistance requirements: Technical assistance must be required and it is important to include this as early as possible within the preparation and planning process to ensure there is a common understanding regarding the objectives and goals of the programme. Many projects and programmes supported by the bilateral agencies and multilateral agencies include technical assistance as an integral part of the work. Where there is co-operation with an national [IREDA – Indian Renewable Energy Development Agency] and international agency, the state agency [TEDA – Tamilnadu Energy Development Agency] will have its own particular criteria for the recruitment of technical assistance. The key staff to work on the programme should have the right expertise and past experience of similar work.

***5) Technical supply options and analysis*:** Decisions about the best technology and about technical details will be dependent on the needs assessment, stakeholder consultation, and other planning variables, in particular the quantitative and qualitative assessment and the determination of priority outcomes and the social context analysis. The resource for different technologies will have to be considered for the site or sites of the programme. The demand (ex: small home systems or much larger systems for small industry) and the load density (e.g. Mini-grid or dispersed systems) have to be taken into account. For example, a small solar home system will typically yield enough electricity to run a few compact fluorescent lights for a few hours each night and a small radio. If a refrigerator is needed, or if a TV will be plugged into the circuit, larger systems will be needed.

Will the programme outcome be affected if the solar resource is only intermittently available? Will a back-up power source be needed? Will down time be acceptable for a small solar home system used to power compact fluorescent lights? Will down time be acceptable for a PV-powered school media system? PV systems (or indeed solutions using other technologies) will need to be designed according to the quantitative and qualitative needs of a specific programme. Details about the size of the system, type of system components (battery, inverter, and modules), availability of alternative power sources and backup power will be decided during the design phase. However, the analysis of different technology options should occur at this stage of programme planning.

6) Programmed budget: The most critical element of any programme is the cost and it is important that realistic and sufficient allowance is made for all those costs that may not appear obvious at first glance. The costs of a PV development project can be broadly broken down as follows:

- planning and project development;
- capacity building and training;
- capital costs (hardware and equipment);
- transportation and installation;
- operating and maintenance costs (e.g., batteries);
- monitoring and evaluation costs.

Planners should keep each of these categories in mind when developing a budget and proposing financing for a programme. It is also important to define how these costs will be met and more importantly who will meet them. This is particularly important when third party financing is being considered – for example, it is important that end-users are consulted if they are going to be expected to meet the costs of operation and maintenance. Effective planning of financing should take into consideration the costs end-users can realistically be expected to bear, and which costs should be absorbed in the broader funding package.

B. DESIGN PHASE

The design phase includes detailed planning to carry out the programme successfully, to address the different costs and benefits identified in the first planning phase. This section highlights a number of issues related to programme design which has to be considered by programme administrators during the process of planning a renewable energy project. During the design phase, one of the most important tasks is to incorporate quality assurance measures into the overall programme design. In order to achieve a project which is successful in the longer term, quality assurance must penetrate all aspects of its implementation. Appropriate procedures need to be put in place that ensure that quality is maintained at all stages of the programme.

At this stage, detailed technical specifications should be developed by technical experts, taking into consideration the results of the needs assessment and stakeholder analysis. This should include details about the size of the system, requirements for system components(battery, inverter, modules), availability of quality equipment, availability of alternative power methods and backup power. In addition, constraints such as climate and solar resource need to be taken into account. Detailed procedures need to be drawn up, covering functionality testing of systems, acceptance testing of components, system installation and system commissioning. Quality assurance requirements should be taken into consideration when these procedures are developed.

Programme planners should work closely with technical experts to ensure that the technical experts understand both the constraints on the programme and the desired outcomes. Technical experts need to remember at this point that models and designs that have worked in other countries will need to be adapted to the specific constraints of the new programme. What has worked in an industrialised country may not work the same way in a developing country because of different social, economic, resource, and accessibility variables.

C. IMPLEMENTATION PHASE

Once thorough programme planning is in place, with time lines, logistics, budgets and team roles delineated, the programme is ready to be implemented. In the implementation phase, quality control and supervision are critical to ensure the desired outcome.

1) Quality control, management and evaluation:

Even the best plans will be subject to contingencies and negligence. Shortfalls in production or quality, programme delays, or budget over-runs must be watched for and corrected regularly as the programme is carried out. Specific time and budget control must be exercised by a recognised project authority. In addition, on-site monitoring of installation quality by persons with technical expertise is important.

Troubleshooting should be an integral part of the programme management. Where shortfalls or problems are found, the PV programme administrators should have a clear policy, known to all personnel involved in the project, for correcting the situation. This might be that all installation work that does not meet quality guidelines, when discovered in a regular inspection, will be re-done. Those responsible for the low quality work will be lectured in some way and corrective training or increased supervision will be provided. Enforcement of programme time plans, milestones, budgets, and quality guidelines should carry clear consequences. Personnel need to know in advance what is expected of them, and then need to know that they will be held to that expectation.

2) Information management system:

If an IMS has been developed, it should be used to its full extent in order to maximise the benefits from it. Relevant information should be captured and entered into the IMS with minimum delay, to ensure that information is always as up-to-date as possible. Reporting functions should be incorporated into the IMS, and should be used for the logistics of the programme. An example would be to generate a report of all sites in a given district which require a visit by installation personnel, either for installation or for rectifying problems. These sites can then all be visited during the same trip, thus making the process more efficient.

3) Training and Capacity Building:

In addition to training carried out during the design phase it is important that training should be on-going throughout the implementation and post-implementation phases. Personnel within the programme and stakeholder groups will change and needs not previously identified may be highlighted. An on-going training programme will ensure that the stakeholders continue to have the necessary skills and that the PV programme is sustainable in the long term.

D. MONITORING AND EVALUATION PHASE

This section deals with the programme monitoring and evaluation. Monitoring and evaluation should already start during the programme preparation and extend through to post-implementation. Even a thorough needs assessment and stakeholder consultation may fail to identify potential negative effects or challenges of renewable energy development. Therefore planning for on-going monitoring is important. Re-assessing the programme after its completion can also allow for unexpected or unplanned consequences to be identified and addressed. For some programmes, the post-implementation evaluation may be appropriate soon after completion of implementation; for others, the evaluation may be most appropriate after a period of a few years after installation.

1) Social, Economic and Environmental Impact Assessment:

During implementation and after completion, an analysis of the impact of the programme on the target group is critical. Have users and other stakeholders reacted as early programme planning indicated? Is the PV technology creating the benefits anticipated? Have anticipated costs and challenges been accounted for?

Social and economic impact assessment involves follow-up with the programme results over time in order to perceive results that may occur as the stakeholders adjust to the new technology. The programme should be revisited, not just to evaluate its performance and quality, but also to look at how it has affected the lives of the stakeholders, over a time frame of at least a year following its implementation. The factors of social context analysis that occurred in the first phase of planning the programme (needs assessment, stakeholder consultation, and social context analysis) should be considered: Social status and interrelation systems, economic systems, family relationships, living conditions, working patterns, village and social interactions, purchasing patterns, and social values. Has the PV programme changed these variables? If so, how is the society responding? Does follow-up training or remediation need to be made?

Similarly, the environmental impact of the programme should be measured during implementation and post-implementation. For example has there been an improvement in the end-users environment? Is the battery recycling scheme being used? Or have there been any adverse environmental impacts that were not envisaged during the programme design?

2) Programme Evaluation:

The programme should be evaluated against its projected targets and milestones as the project proceeds. Once implementation is complete the programme goals and objectives should be considered against the programme outcomes. At the beginning of the programme, metrics for the success of the programme should be developed using the goals and objectives of the programme. Solar Home Systems [SHS] might improve family health by eliminating oil or kerosene lighting smoke, and increase people's quality of life by reducing the amount of money spent on traditional fuels. Basic lighting might allow students to study after dark, contributing more time to farming during daylight, thus increasing family income while simultaneously achieving educational goals. Basic lighting may allow a house owner to take on small piece work and create a home business, increasing his or her standard of living.

Given the specific desired outcomes from the PV programme, the evaluation determines how and to what extent those goals are being realised. Measurements of community small business increases, income increases, agricultural output increases, educational opportunities, health improvement, or payment for services/repayment of loans can be made, depending on the specific outcomes desired, to demonstrate the success of the programme. Statistical surveys may need to be undertaken to assess the degree to which the PV programme has achieved desired micro-level benefits. If technical problems are experienced a technical evaluation may be required. This would require technical experts to thoroughly inspect systems or inspect at least a sample of all systems installed, in order to assess technical failures or shortcomings, which might be due to poor system design, poor quality of components, poor workmanship during installation, or the use of inappropriate loads by the user.

Mini PV powered lighting system structure has been designed [Figure 1], analysed and tested in power grid equipped house as a partial lighting system with cost analysis.

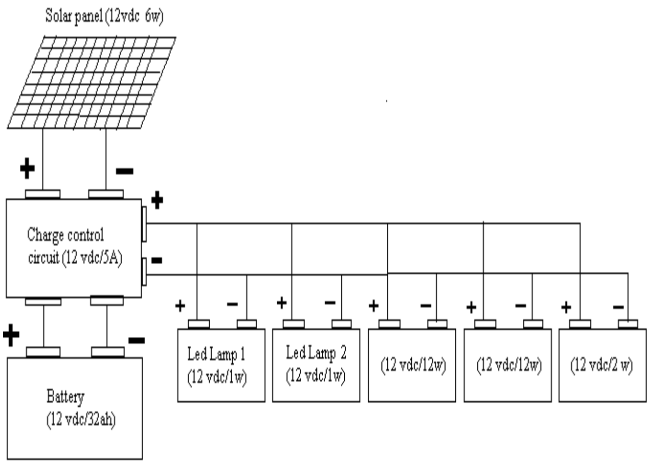

Figure 1: Mini PV powered lighting system

My House has 5 FL [Tube lights] each equipped aside with LED lamps

a) Utilization and cost analysis

Non – PV equipped House:

- 5FL * 40 watts = 200 watts

  200 watts * 5 hours = 1000 watt hours [1 kwh] / day used [normal use]

PV equipped House:

- 1FL * 40 watts = 40 watts;
  (40 watts * 5hours = 200 watt hours);
- 4FL * 40 watts = 160 watts; 160 watts;
  (160 watts * 1hr = 160 watt hours);

Total watt hours = 200 + 160 [360 watt hours] / day used.

Difference = 1000 watt hrs [Non-PV] – 360 watt hrs [PV] = <u>640 watt hrs / day saved</u>

640 watt hrs * 30 days = 19,200 watt hrs/month saved [19.2kwh – 19.2 units]
640 watt hrs * 365 days = 2,33,600 whrs/ year saved [233.6kwh – 233.6 units]
19.2 units * Rs. 3 [Ave – Subsized] = Rs.57.60 saved/month
233.6 units * Rs. 3 [Ave – Subsized] = Rs.700.80 saved /year for single house
The above details shows the utilization of the PV powered mini lighting system and its corresponding cost analysis.
b) Nationwide benefits
640 watt hrs * 365 days = 2,33,600 whrs/ year saved [233.6kwh - 233.6 units]
233.6 units * Rs. 3 [Ave – Subsized] = Rs.700.80 saved /year for one single house
For 100 houses @ ketti – one single village
[Remember ketti and around there are more than 1000 houses]
100*233.6kwh = 23,360 Kwh for single village
[India has more than 1,00,000 villages]
1,00,000*23,360 = 23,360,00000 kwh = 23,36,000 mega watt hours can be saved Nation wide.
The above details shows the benefits PV powered mini lighting system deployment in all the Indian houses and its corresponding energy saving facts.

CONCLUSIONS

The planning of a PV implementation programme is a fairly complex process. A large number of issues have to be taken into considerations and many individual tasks are necessary. Neglect of some of these tasks may result in problems later on or, in the worst case, to failure of the programme. This paper lists issues to be considered which are typical for most PV programmes or projects. However, each programme is different and special circumstances will require special consideration. Therefore it is necessary to assess the requirements of each programme individually.
During the preparation phase of a programme, it is essential to determine whether a programme fits into overall national goals and objectives. Needs assessment and stakeholder analysis should be carried out.
During the design phase, the programme is planned in detail. This includes financial, logistic, personnel and technical planning. During this phase, it is important that quality assurance aspects are incorporated into the programme design. Ongoing maintenance must also be considered.
During implementation, it is important to check progress and to take corrective action if anything goes wrong. Programme evaluation should also take place, looking at the social and technical performance of a programme, measuring the results against the original objectives. Mini PV powered lighting system structure has been designed, analysed and tested in power grid equipped house as a partial lighting system with cost analysis.

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