Addis Ababa Institute of Technology
School of Graduate Studies
Energy Center

Optimizing the Technical and Social Benefits of Solar Photovoltaic Technologies in Ethiopia.

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Advisor
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Signed Declaration

I declare that the research for the M.Sc. degree at the University of Addis Ababa, hereby Submitted by me, is my original work and has not previously been submitted for a degree at this or any other university, and that all reference materials contained in that have been accordingly acknowledged.

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Abstract

Despite the abundance of renewable energy resources in the country, the rural and urban communities in Ethiopia are suffering from shortage of electricity. The grid electricity could not reach many areas due to inaccessibly related to remoteness. Solar energy, a resource widely available throughout the country, is also not utilized. Accordingly, this study tries to identify limits on technical and social benefits of solar photovoltaic technologies in Ethiopia thereby its use to increase electricity access. Thus we assess factors affecting the dissemination activities, such as solar PV installation practices, Solar Home and institutional system distribution strategies, system failures and their causes. To conduct this research, we performed desk reviews, Key informant interview, focus group discussions and field surveys. In addition, we analyzed the impact of PV orientation by comparing simulation result made by PVsyst software at various angles observed during field survey. One Kebles from each four regions, namely SNNPR, Amhara, Oromia and Tigrai regions were selected, where about 20 households were surveyed. In doing so, Factors affecting the dissemination activities as well as best orientation were able to be determined. The study also assess that, how Availability of replacement and maintenance, lack of Public awareness creation and institutional problems, tariff and shortage of market can affect the accessibility and large scale distribution of PV system.

In order to disseminate the solar PV in ample amount throughout the country, this study would like to recommend that factors affecting the distribution needs to be considered at all levels in way to achieve maximum result, technical capability of the solar PV needs to optimized through appropriate installation with a recommended tilt and azimuth angle. By doing so, the vision that we aspire to have sustainable energy supply in the country as well as a reduce level of emission from biomass will be garnered.

Key Words: *SHS and institutional PV systems, social benefit, factors affecting solar PV dissemination, orientation optimization, tilt angle and azimuth angle, modeling.*

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Abbreviations

FDRE -Federal Democratic Republic Ethiopia

UNDP-United Nation Development Program

GEF-Global Environmental Facility

USD/US$-US Dollar

CRGE-Climate Resilience Green Economy

NICP-National Improved Cook stove Program

IFC-International Finance Cooperation

REB-Rural Electrification Board

IDCOL- Infrastructure Development Company Limited

GW-Giga Watt

SREP -Scaling-up Renewable Energy Program

MoWIE-Ministry of Water, Irrigation & Electricity

GTP-Growth and Transformation Plan

MW-Megawatts

REF -Rural Electrification Fund

NGO -Non-Governmental Organization

CFL - Compact Fluorescent Lamp

LED - Light Emitting Diode

PV –Photovoltaic

OECD – Organization for Economic Cooperation and Development

AETDPD- Alternative energy technology development and promotion directorate.

BOS - Balances of System

BIPV -Building –Integrated PV

WRDC - World Radiation Data Center

NASA-SSE - National Aeronautic Space Agency Surface Meteorological and Solar Energy Programme

GIS-ESRA - Geographical Information System-European Solar Radiation Atlas

METEOSAT - Meteorological Satellite

MDG - Millennium Development Goals

SHS - Solar Home System

SNNP - South Nations Nationalities and Peoples

DBE - Development Bank of Ethiopia

RET - Rural Energy Technologies

SME - Small Microenterprise

MFI - Micro Finance Institution

LVD - Low Voltage Difference

HVD - High Voltage Difference

Lat. - Latitude

Long - Longitude

Alt - Altitude

KWh/m^2.day - Kilowatt-hour per Meter square per Day

KWh/m^2.year - Kilowatt-hour per Meter square per year

FTranspose - Transpose Factor

Loss/Opt. - Loss per Optimal

DB - Distribution Box/Board

DC - Direct Current

AC - Alternative Current

ROI - Return on Investment

PPE - Personal Protective Equipment

Ah - Ampere hour

A - Ampere

NA - Not Available

Vdc - Direct Voltage

Vac - Alternating Voltage

mm^2-Millimeter square

LCOE – Levelized Cost of Electricity

W –Watt

KW- Kilowatt

FGD - Focus Group Discussion

GIZ - German Development Cooperation

CHAPTER - ONE

1. INTRODUCTION

1.1. BACKGROUND

Ethiopia's energy need is increasing in rapid rate; this is mainly due to population growth, the high economic activity and social life style change, which entails the production of huge amount of electric power to be distributed to all households and industries [1]. The majority of Ethiopia's population lives in rural areas and very few have access to electricity [2]. The electricity supplied to those who have access comes from renewable energy. But most of the energy need of the rural community and even the cooking energy need of the suburban population are supplied by biomass, which traditionally serves the rural community as a fuel for cooking, heating, and off-grid lighting [2].

Ethiopia has introduced solar electricity in the mid 1980’s [1]. During GTP-1 (2011), more than 3 million solar photovoltaic systems was planned to disseminate by the end of 2015[3]. However, the target has not been achieved yet even with efforts from the Rural Electrification Fund (REF), private solar companies, NGOs, and foreign aid missions.

Solar photovoltaic provides clean, safe and environmentally friendly energy; it can also have many positive impacts interms of women’s welfare, children’s education, and employment and income generation. However, the high cost, unreliable technical performance and lack of trained personnel to take care of the system have inhibited the use of PV on a large scale [4]. Studies conducted elsewhere reveals that appropriate financial mechanism suited to the local conditions need to be in place for wider dissemination of PV systems, as the initial cost for individual users is high [5]. It was also shown that Poor technical performance is often a result of selecting inappropriate accessories of PV systems and lack of proper maintenance [6]. Therefore, by using this assumption, this research paper tries to analyze the existing social and technical challenges in small scale PV system dissemination in the context of Ethiopia. Moreover this research focuses on examining the case of solar home system and remote institutional systems which is installed by MoWIE. This study will therefore provide important lessons regarding its dissemination, installation as well as the system component availability and use.

1.2. Statement of the problem

The electricity consumption rate in rural Ethiopia is very low compared to that of the urban coverage. This is mainly due to the financial difficulty of connecting the rural population living in isolated villages to a centralized electric grid [7-8-9]. Studies show that solar home systems are the ideal, environment friendly and sustainable means to provide electric power to such scattered rural villages. PV dissemination, and installation and maintenance practice in Ethiopia is facing many challenges. The most important challenge is that most of the households in the rural villages depend on cheap kerosene lamps for lighting, and on fire wood and charcoal for cooking need. As related to installation problems, it was observed that some installations appear to be at very high tilt angle and wrong panel facing while others are sited under shadow. At the same time, several customers are complaining due to the absence of frequent maintenance and replacement. This is because of alleged component failures and an availability of required spare parts and the short battery life time of approximately 4 years. However, it is well known that the dissemination of small solar systems provides several benefits to rural communities. Among the benefits are to enable the rural population to have access to evening education, mobile phone charging services, enabling information access through the possible use of radio, television and mobile applications. This research investigates the nature of PV dissemination process so as to identify factors affecting its adoption. By the same way, it also aspires to look at issues that would optimize its benefit by way of technical evaluation as well as comparison of the local practices with the experience of other countries. The specific research questions are designed as follow.

1.3, Research Questions

- What are the challenges of solar PV dissemination in Ethiopia the case MoWIE?
- What are the conditions that can decrease solar PV system performance after installation?
- At what tilt and azimuth angle solar PV systems can generate maximum energy output in Ethiopia?

1.4. Objectives

1.4.1. General objective:

The general objective of this research is, to “Optimize the Technical and Social Benefits of Solar Photovoltaic Technologies in Ethiopia” at household and institutional level, by identifying those factors that determine their performance thereby contributes for maximum social benefit, taking the case of ministry of water irrigation and electricity.

1.4.2. Specific objectives:

- To assess the distribution of solar PV systems installed by ministry of water irrigation and electricity at household and institutional level during GTP-1.
- To assess the challenges during distribution and installation.
- To observe and inspect panel orientation of SHS and institutional systems.
- To model solar PV orientation for Adama, Hawassa, Bahir-dar, Mekele and Addis Ababa areas for optimal energy output throughout the year.

1.5. Scope and Significance of the Study

The findings of this study could be used to fill the huge gap between energy demand and supply, especially in the rural part of Ethiopia and to improve the current solar dissemination and installation practice in Ethiopia. To conduct the study, mainly solar systems which are installed by ministry of water, irrigation and electricity at household and institutional level at rural and urban areas were used. The main study units were household systems, primary school and health post solar PV systems. After the study has been completed it provides comprehensive information on solar PV dissemination strategy. It could also be useful to identify clear guideline for PV installation for optimal energy output throughout the year in order to maximize social benefits. This guideline can be used by governmental bodies, stakeholders, non-governmental organization, contractors etc.

CHAPTER– TWO

2. Literature Review

2.1. Global Overview of PV Market and Dissemination

Solar Photovoltaic is one of the fastest growing renewable energy technologies today and is projected to play a major role in global electricity production in the future [10]. By the end of 2014, cumulative photovoltaic capacity increased by more than 40 giga-watts (GW) and reached at least 178 GW, sufficient to supply one percent of the world's total electricity consumption of currently 18,400 TWh [11-12]. According to EPIA, 2013-2-2017 projection for global market outlook for photovoltaic's, Europe remains the world’s leading region in terms of cumulative installed capacity, with more than 70 GW as of 2012. This represents about 70% of the world’s cumulative PV capacity (compared to about 75% of the world’s capacity in 2011). Next in the ranking are China (8.3 GW) and the USA (7.8 GW), followed by Japan (6.9 GW). Many of the markets outside EU in particular China, USA and Japan, but also Australia (2.4 GW) and India (1.2 GW) have addressed only a very small part of their enormous potential. Currently the biggest emerging markets are China, the Middle East, South Korea, India and other Southeast-Asian countries. Although emerging PV markets will probably not grow by as much in absolute terms as Europe has done inrecent years, growth in these markets looks set to be sustained. In addition, several countries from large Sunbelt regions like Africa, the Middle East, South East Asia and Latin America are on the brink of starting their development, representing big PV market opportunities for the future.

2.2. Factors affecting PV market

PV is a mature, proven technology that is rapidly approaching grid parity. Despite this fact, the global PV market growth is below manufacturer’s capability [13]. The major reasons for this were that PV electricity was four to five times more expensive than fossil fuels forcing the potential customers to prefer fossil fuels than PV system. This high cost was mainly due to the high capital cost, the running cost and low efficiency. Better efficiency improvement has been obtained after improvements of the parameter (inverter, charge controller, batteries) through innovation. Incentive driven (feed-in tariffs and tax breaks) rapid expansion in capacity has led to significant cost reductions. The learning rate for the price of PV modules is estimated to be around 20% to 22% (23% to24% for thin films and 19% to 20% for c-Si), which means each time the cumulative installed capacity has doubled; PV module costs have declined by 20% to 22% [13]. In addition to the abovementioned reasons that hinder PV market, the following major points present other challenges more specific to small scale PV markets.

I. Demand structure

An often repeated explanation for the growth of the SHS market segment in Kenya is the general rise of an affluent rural middle class from around the 1990s, which increasingly demanded electricity to power televisions, radios, cell phones and other modern electronic appliances [14]. The increasing income from tea farming was particularly important in improving the purchasing power of these rural customers. The development of the SHS market segment was mainly attributable to high incomes among farmers (coffee, tea, and horticulture), rural teachers, civil servants and businesses with a strong demand for consumer electronics (TV’s, radios, cell phones) [14]. Consequently, the business model of many PV system suppliers in Kenya was to target this growing rural middle class that lacked access to electricity(most buyers are rural middle-class households that lack confidence that the power grid will be extended), who are knowledgeable about photovoltaic system performance by making existing battery systems less maintenance intensive. Local entrepreneurs have played a key role in the process by aggressively moving photovoltaic systems to market and by downsizing the product to the needs of the lower-income market. This would indicate that, besides the effects of the demand from the rural middle class, the lack of prospects for grid connection was an important factor for customers in deciding to purchase SHS. At an early point in the market’s development, ‘an enormous demand for electricity in rural areas has gone unsatisfied because they cannot count on grid connection. As a result, rural households have increasingly turned to photovoltaic to meet their electrification needs [15]. More recently studies stressed that ‘a major characteristic that probably helps to explain the high adoption rate of PV systems in rural Kenya is the slow pace of the grid extension’, which was associated with the ineffective rural electrification programme in Kenya [16].

II. Geographical conditions

A number of papers employ a geographical explanation for the disparate patterns of SHS market development in Kenya, Tanzania and Uganda. The Tanzanian population is more geographically spread compared to Kenya, where a majority of the population is concentrated in the central and western parts of the country [17]. Coupled with a relatively well-developed transport infrastructure in terms of road and rail links, establishing effective distribution channels and a PV supplier network has therefore been easier in Kenya. This shows that, distribution linkages are poorly established across Tanzania, partly due to the geographical size of the country and the geographical distance between players being a major barrier to the development of the market. And geographical proximity between the PV industry, which is concentrated mainly in Nairobi, and market demand, as the customers (living mainly on the southern and eastern sides of Mount Kenya) were located relatively close to the suppliers. The close distance between the PV supplier industry and the end-market is seen as a key explanation for the initial growth of the commercial SHS market in Kenya during the 1990s [17].

III. Local champions

Two expatriate engineers in particular have been widely cited as playing a key role in the initial development of the SHS market segment in Kenya [18]. The private market's genesis may be roughly dated as 1984 at the same year, an American engineer, Harold Burris, founded a small company called Solar Shamba' [19]. According to Mark Hankins 'Burris trained a group of about a dozen local technicians to market and install PV lighting systems. By reaching out to the high-income households on the southern and eastern sides of Mount Kenya, the rich white coffee and tea farms and Burris' successes attracted other local entrepreneurial groups and individuals to join the rural PV market.

IV. Business culture

The convenient regulatory and solar business environment in Kenya plays a key role in stimulating the SHS market by pointing to a strong entrepreneurial culture and openness to foreign investors and business practices/ideas, while deploring that the lack of entrepreneurs hindered the emergence of successful solar companies in Tanzania during the 1980s and 1990s'.

Similarly, the opportunistic behavior of entrepreneurs once the demand had been demonstrated was a key to promoting market development, thus pointing to the widespread opportunism and risk willingness of local firm’s in Kenya to enter the PV market during its initial development [19]. These findings link the emergence of a PV market mainly with the existence of a particularly dynamic and entrepreneurial business attitude in Kenya.

V. Batteries and components

The PV module cost is typically between a third and a half of the total capital cost of a PV system, depending on the size of the project and the type of PV module [20]. The absolute cost and structure of PV modules varies by technology. Conventional c-Si PV modules are the most expensive PV technology, with the exception of CPV modules, but they also have the highest commercial efficiency. However, CIGS modules are approaching the efficiency levels of c-Si modules and are cheaper. Accurate data on global average PV module prices are difficult to obtain and in reality there is a wide range of prices, depending on the cost structure of the manufacturer, market features and module efficiency. However, an estimate for the global price of c-Si PV modules in 2008 was USD 4.05/W and this had declined to USD 2.21/W in 2010 [20], a decline of 45% in just two years. The rate of decline in costs has not slowed and by January 2012 spot market and factory gate prices in Europe for low-cost Chinese and other emerging market manufacturers of c-Si modules had dropped to around USD 1.05/W [21]. Spot and factory gate prices for c-Si modules from European, Japanese and other manufacturers had declined to between USD 1.22 and USD 1.4/W by the fourth quarter of 2010, the cost of monocrystalline silicon PV modules in Europe was between USD 1.43/W (emerging economy manufacturers) and USD 2.21/W (high efficiency c-Si modules), while thin-film PV modules cost USD 1.27/W. In the United States, the price range for monocrystalline silicon PV modules was between USD 1.74/W and USD 2.53/W, with thin-film PV modules costing USD 1.19/W. In general, factory-gate prices appear to be slightly higher in the United States than in Europe. This is perhaps due to the higher support offered by United States’ policies in 2010. Also, Chinese modules tend to be cheaper than modules from OECD manufacturers [22].According to pvXchange, the world’s largest brand-independent marketplace for solar modules, the global blended average price for a tier-1 Chinese-produced multi crystalline PV module fell 10 percent year-over-year and reached 57 cents per watt in the fourth quarter of 2015 [23].

“While underwhelming demand in 2014 left its trace on pricing in early 2015, supply-demand tightness and tariffs drove price trends in the second half of the year,” said Jade Jones, a senior solar analyst at GTM Research. Assuming a stable supply-demand landscape, GTM Research anticipates that global blended prices will steadily fall at an annualized rate of 5 percent and reach 44 cents per watt by 2020[23].

The LCOE of PV systems is also highly dependent on BOS and installation costs, which include: the inverter, which converts the direct current (DC) PV output into alternating current (AC); the components required for mounting and racking the PV system; the combiner box and miscellaneous electrical components; site preparation and installation (i.e. roof preparation for residential systems, or site preparation for utility-scale plants), labor costs for installation and grid connection; battery storage for off-grid systems; and system design, management, installer overhead, permit fees and any up-front financing costs. Rooftop-mounted systems have BOS costs around USD 0.25/W higher than ground-mounted systems, primarily due to the additional cost of preparing the roof to receive the PV modules and slightly more costly installation. In absolute terms, the electric system costs are roughly the same in both systems and account for around one-third of the BOS costs in ground-mounted systems and somewhat less in residential rooftop systems due to their higher BOS costs. The inverter is one of the key components of a PV system. It converts the DC electricity from the PV modules into AC electricity. Inverter sizes range from small textbook-sized devices for residential use to large container-sized solutions for utility-scale systems. The size and numbers of inverters required depend on the installed PV capacity and system design options. Inverters are the primary power electronics components of a PV system and typically account for 5% of total installed system costs. Currently, inverter cost ranges from USD 0.27/W to USD 1.08/W, depending on the system size [23]. Larger systems tend to have lower inverter costs per unit of capacity, with systems in the 10 to 100 kW range having costs of between USD 0.23 to USD 0.57/W. However, some of the most competitive inverters for small-scale applications (<5 kW) can rival those costs, as the range in 2012 was USD 0.30 to USD 1.00/W [24].

In addition, to support argument regarding the above mentioned factor, the kenyans’ situation were reviewed, and showed that, development of a local battery supplier industry during the 1990s in Kenya is seen as a key factor for PV market development and in particular emphasizes that technical modifications, known and utilized in the manufacturing of batteries for other applications for years, improved PV system performance [24]. These points towards cross-fertilization of the technical development mainly of car batteries to suit PV systems and thus a fruitful interaction between two emerging industries in Kenya, increase in the local availability of components such as batteries, wiring, circuitry and charge controllers in Kenya lead to substantial decrease in PV system costs, as this reduced the need for imports, which contributed to stimulating market development. Similarly, the successful development of the household and small commercial system markets is attributable to the availability of balance of systems components and local battery manufacturing. As a result of this South Africa and Kenya are, therefore, the only African countries with a sizable production capacity for solar modules, balance of system (BOS) components and lead acid batteries. It, thus, serves not only as an import hub, but also as a manufacturing centre for the wider region. Therefore, it can be stated that, balance of system cost has a paramount factor in PV market development.

2.3. PV dissemination challenge

Worldwide PV is currently the fastest growing renewable energy technology [25]. This is mainly due to a combination of economies of scale and market development in selected countries in Europe (Germany, Italy and Spain), China and the US created by favorable framework conditions, such as feed-in tariffs. In the period from 2008 to 2013 this lead to a decrease of 60% in residential system prices in the most competitive markets and a decrease in module prices of 80% [25].

The main PV diffusion barriers and systemic problems that have constrained the diffusion of solar innovations in Ethiopia is, the lack of integration among solar actors and the financial problem facing both sides of the supply chain have been identified as critical factors behind the slow rate of diffusion [26]. This diffusion process suffers due to various reasons. Acceleration of diffusion of PV based electricity generation systems is found to be greatly promoted by integrating the supply and demand side of the diffusion process [27]. On the demand side, investments required by individual households are considerable, and so access to financial resources can be a fundamental constraint on the diffusion of PV technologies. On the study of World Bank lending schemes to India, Indonesia, and sir lanka, they highlight that access to credit is the single most important factor influencing the diffusion of SHS [28]. On the supply side, policies to promote market infrastructure, namely, distribution, installation and servicing are essential. Among the many futures that play an important play is the elimination or phasing out of import duties and local taxes on PV modules.

Generally, there is no single best organizational model to promote dissemination of SHS. On the other hand, dissemination depends on institutional, legal, socio-economic and cultural conditions in the country/region. Studies conducted in India, Indonesia, and sir lanka illustrates that the factors contributing to the successful promotion of PV based rural electrification are; suitable financing schemes to address the problem of high initial cost, means of providing regular and proper maintenance (including maintenance done by consumers that requiring trained personnel) and availability of spare parts and choice of available configurations to suit the consumers' need and affordability [29]. Some of the main challenges for PV dissemination are presented below.

A. Lack of implementation strategy

The global diffusion of renewable energy technology (RET) has been sluggish, and as a result governmental support and policy interventions have been required [30]. Demonstration projects serve to introduce the selected technology, to be then expanded on the bases of development of local companies and trainings. Government could accelerate the dissemination by removing barriers to market expansion, by removing excessive duties and taxes, and by removing subsidies on products which compete with PV. They also list the role of key players involved in the promotion and dissemination of PV systems in developing countries such as governments, donor agents, electric utilities, educational and research institutions and private sectors, NGOs and etc. It is important to note that absence of such implementation strategies and active participation of stake holder would results in inefficient PV system dissemination [30].

B. Lack of maintenance and availability of various system sizes

The success of solar home systems programs in South Pacific countries were linked to the provision of good maintenance services by local and other technicians, regular fee collection, availability of systems of various sizes to meet different needs, continued internal and external training of personnel [31]. Case studies conducted in Ethiopia revels that, local presence and after-sales service of solar PV are among the key factors in the diffusion of SHS. Unavailability of this all experiences can cause bad customer attitude towards the technology [31].

C. Existence of financial and institutional barriers

A successful PV market development for rural electrification requires the removal of financial and institutional barriers. The other major issues to be considered are the high initial cost, establishment of a responsive and sustainable infrastructure and ensuring quality products and services [32].

D. Overlooking the customer value

A study conducted in Indonesia, Sri Lanka, the Philippines, and the Dominican Republic have shown that customer value certain advantages of PV based electrification, for instance services such as good quality lighting, clean indoor air, access to TV and radio and elevated social status. Accordingly, SHS installation should ensure the satisfaction customer expectation [33].

E. Luck of appropriate policy development and capacity

Report on a study of 12 energy service projects SHS funded by world bank groups since 1992, have identified the following basic futures for a sustainable PV market development: financing (based on private sector or NGOs, consumer credit delivery mechanism or ‘pay first’ cost subsidies); appropriate policy development and capacity; development of standards and codes, establishing enforcing institutions; and creating consumer awareness [34]. They also note that the demonstration of viable business model is key to achieve project sustainability and replication.

2.4. Current Trends of PV Dissemination Practice in Ethiopia

I. Ethiopia Energy Policy and Legislative context

In 1994, a National Energy Policy was adopted in Ethiopia [35]. A recent draft of the updated Energy Policy from February 2013 states that the principal goal is to ensure the availability, accessibility, affordability, safety and reliability of energy services to support accelerated and sustainable social and economic development and transformation of the country [36]. The draft Energy Policy seeks to improve, the security and reliability of energy supply, enable Ethiopia to become a regional hub for renewable energy, increase access to affordable modern energy, promote efficient, cleaner and appropriate energy technologies and conservation measures, strengthen energy sector governance and build strong energy institutions, ensure environmental and social safety and sustainability of energy supply and utilization as well as strengthen energy sector financing. While the principal goal of the updated national Energy Policy is to promote and support expansion and promotion of small-scale renewable energy technologies and grid electricity, there is also an emphasis on improved cook-stoves for rural household use [36].

II. Development of National Rural Energy, Regulatory and Legal Framework

Ethiopia has a Rural Renewable Energy Policy Framework and an updated Energy Policy [36]. Under this framework, Ethiopia has a vision of becoming a renewable energy hub by 2025 and for the energy sector to play a significant role in socio-economic development and transformation of the country through provision of a sustainable, reliable, affordable and quality energy service for all sectors in an environmentally benign manner [36]. This includes the strengthening of the legislative and regulatory basis for supporting the widespread dissemination of small-scale renewable energy technologies by focusing on amendments to legislation and the introduction of new regulations in a manner that is consistent with the new Energy Policy. In particular, this requires the development of technical standards to promote the further development of the market for small-scale solar technologies.

III. Development of Renewable Energy Technology Enterprises

To grow opportunities for new technology applications and investment in the small-to-medium enterprise sector, the Government of Ethiopia is looking to provide incentive schemes including tax relief, lowered investment capital requirements, access to land, provision of accessible finance and technical assistance to green ventures. The Ethiopian Climate Innovation Centre offers enhanced services (selection of promising enterprises, provision of comprehensive training, and start-up financing) to small and medium enterprises that are very much in line with the goals of the rural energy technologies (RETs) characteristics [37]. The Entrepreneurship Development Centre, supported by UNDP and the Horn of Africa Regional Environment Centre & Network, is an additional important partner for supporting local RETs enterprises [38].A number of specific training centers for solar technologies have been developed, for example, the

Solar Energy Foundation and specific courses are offered in Technical Vocational Education and Training institutes [39].

IV. Dissemination of Rural Energy Technologies in Ethiopia

In Ethiopia, currently small-scale solar technologies mainly solar home system dissemination activities are ongoing particularly in the four major regions of Amhara, Oromia, SNNP and Tigray [40]. Specific RET programmes, such as the NICSP, REF and Lighting Africa Ethiopia, are considered key baseline activities upon which the UNDP implemented, GEF-financed project will build to leverage further investments from the private sector (end-consumers and RET enterprises) in a commercial manner. The REF's future role will be mainly in awareness creation, promotion and technical support provision for consumers (and especially also women's groups playing an important role at household level), developers, businesses and financial mediators such as banks and micro-finance institutions [41]. The REF, in collaboration with Regional Energy Bureaus, provides support to identification and organization of rural consumers, including households and institutions, and facilitates the means to access off-grid electricity and lighting technologies and services through the private sector [41]. The Development Bank of Ethiopia and selected micro-finance institutions provides financial leverage to the private sector for import and wholesaling, retailing and acquisition of alternative energy technologies, including off-grid lighting products such as solar lanterns and solar home systems. The lending so far of USD 20 million by the World Bank to the Development Bank of Ethiopia for the Electricity Network Reinforcement and Expansion Project is seen by all stakeholders as the key source of capital for financing the loans required by consumers, co-operatives and enterprises to buy, manufacture, distribute and sell rural energy technologies [42-43].

V. Strengthened National Regulatory and Legal Framework

A key issue concerning the National Energy Policy of Ethiopia is that there is no authority or agency responsible for introducing rural energy initiatives other than for expanded grid electricity and petroleum products [43]. In addition, the Climate Resilient Green Economy (CRGE) strategy for Ethiopia is mainly focused on expanding utility-scale electricity generation and extending the grid. There is no national regulatory and legislative framework for renewable energy for the rural sector and no incentives to specifically promote and encourage renewable energy for rural populations. In addition, there is no legislation or regulations currently enacted which provide up-to-date technical standards for small-scale renewable energy technologies or for improved cook-stoves [43]. Development of standards for RETs is therefore vital and needs stronger emphasis by the government. The Rural Electrification Fund (REF) of MoWIE, with a capitalization of under USD 2 million and limited capacity, does not have the ability to finance a large number of small-scale renewable energy projects. It is important to strengthen the institutional capacity of MoWIE's Alternative Energy Technology Development and Promotion Directorate (AETDPD) and of the REF to promote small-scale renewable energy solutions to rural communities and to develop and enforce relevant policies and regulations. Ensuring product quality is a key concern stressed by all relevant stakeholders (Ministries and Government agencies, development partners, RET enterprises). Stakeholders emphasize the central role that the Ethiopian Customs Service, importers, distributors and retailers must collectively play to ensure against poor-quality or inferior products reaching consumers and to strengthen the integrity of the market [43]. Mislabeling of imported products in particular has lead to past product underperformance and failure in the marketplace. In turn, user disappointment has adversely affected consumers' impressions of the technology and diminished their willingness-to-pay to acquire or replace faulty systems. To address this challenge, working on technical assistance on RET technical standards and regulations for rural energy technologies. Training packages for the roll-out and enforcement of product standards and conformity-testing will help to ensure that imports are correctly labeled, renewable energy components are treated consistently, and consumers receive quality products. Quality certification and labeling programmes such as those being implemented by the World Bank and the International Finance Corporation's (IFC) Lighting Africa initiative can provide a best-practice approach for the Ethiopian market [43]. Nevertheless, additional GEF support is required to review the development of technical standards and regulations and prepare a strategy for rolling them out to the market. There is a lack of awareness among rural populations in Ethiopia of the possibilities for gaining access to energy, including renewable energy. Public awareness campaigns have typically been targeted at urban areas and have neglected important gender-sensitive messages that recognize the important roles of women and female household heads in making purchase decisions; appliance manufacturers have also focused on urban populations, where the ability to pay for renewable energy technologies is higher. The lack of awareness is made more acute by the absence of appliances such as televisions and radios in some rural communities, making these advertising channels unavailable. Public awareness campaigns need to be carefully designed and targeted in order to best overcome these barriers. It is important for the campaigns to solicit feedback and comments from consumers, local governments and NGOs in order to better understand what is effective[43]. In addition, market actors, most notably solar lantern and solar home system providers face lack of support in marketing and promotion of rural energy technologies. It is therefore important to involve the private sector in public awareness campaigns and marketing of specific RETs to communicate the benefits of these technologies to promoters and users. Weekly markets are usually key entry-points to demonstrate technologies directly, gain exposure and help consumers become more acquainted and comfortable with products. Inclusive awareness creation such as (equally considering the needs of women, men and children) farmers who are considered respected leaders in rural areas need to become key partners in helping suppliers and distributors increase awareness and interest in off-grid technologies.

VI. Affordability of Small-Scale Renewable Energy and Financial Support Mechanism

Lack of affordability of household energy appliances among rural populations, where the majority of people earn less than USD 1 per day, is a significant issue [44]. A financial support mechanism (e.g. performance grants, revolving fund, investment fund, micro-credit scheme, carbon finance, etc.) that would help to subsidies the cost of these appliances or provide households with access to credit is needed to enable them to make purchases that would normally simply not be affordable[44].The disappointing performance of the Rural Electrification Fund (REF) over the past ten years starkly demonstrates the difficulty of implementing a private sector approach in rural Ethiopia, where inability to pay is such a significant barrier. In addition, the development of business skills and small-scale entrepreneurship will help to ensure that solutions are sustainable. A number of enterprises seeking to deploy small-scale, off-grid technologies emphasize that the lack of financing options is among the most significant barriers to project deployment [45]. Thus, improving access to financing should be a top priority for enhancing off-grid electrification. The development and commercial banks' collateral requirements, relatively high interest rates and short payback periods have hitherto rendered these options prohibitive. Further, lenders' lack of familiarity with rural energy technologies, among both commercial and micro-finance institutions (MFIs), has increased the perceived risk of these projects and limited lending to the nascent sector. MFIs lack the necessary technical knowledge to assess off-grid projects and are, therefore, unwilling to lend to projects. As a result, enterprises have not been able to secure the necessary start-up capital. The experience and expertise of the Clean Start Programme will be critical in helping to overcome the financial barriers by establishing a credit de-risking facility for the Development Bank of Ethiopia (DBE) and micro-finance institutions (MFIs), as well as capacity-building for these financial service providers to assess, develop, deploy and scale-up micro-finance products to finance sustainable rural energy technologies to low-income households and RET enterprises [45].

VII. Lack of enterprises involved in supplying

There are four principal reasons why there is a lack of enterprises and businesses successfully supplying renewable energy technologies to rural communities in Ethiopia [45]. The first reason is that the urban market is more lucrative, with urban customers having higher incomes and higher ability to pay compared to the rural market. Second, the rural setting isolates many rural communities and there is additional time and cost (low economies of scale) involved in travel to these rural areas. Economics does not make it attractive to establish shops or supply centers in remote rural communities. Third, donors have unwittingly undermined the market for enterprises interested in supplying rural communities with energy-related appliances. Donors that give away appliances for free are a much more attractive option for rural communities than enterprises that sell their appliances. The fourth reason is a lack of business skills and start-up capital for enterprises to enter the market [45]. Awareness of innovative technologies is required, as well as institutional support to train business operators and enterprises in improving their skills and readiness to start-up and operate a RET business. Technical and business-development skills at basic and advanced levels are required for innovators to develop. In addition, a "one-stop-shop" for enterprises at the level of regions and woredas would allow micro-enterprises to receive relevant information regarding business.

2.5. Best Energy Lessons of Selected country

A selection of case examples is provided below to illustrate how the institutional frame just described has been successfully applied to create vibrant renewable energy industries. As the case examples illustrate this general framework is implemented across countries differently with some functions being more important than others in developed and developing countries.

Germany: Germany has the largest installed renewable energy capacity and the largest renewable energy market in the world [46]. It also has a large renewable energy industry employing more than 350,000 people [46]. German companies are now industry leaders in many fields. The renewable energy sector in Germany took off after the Feed in Tariff of 1991 and the Renewable Energy Resources Act in 2000[46-47]. The FiT and the Act were issued to promote energy security, climate sustainability, domestic industry, jobs and innovation. Regulations subsidy policy based on feed-in tariff that was established in 1991. Renewable resource specific Feed in Tariff (FiT) has been the main instrument of promotion of renewable [47]. Ten years after the Act was issued more than 24GW of PV capacity was fed into the grid [48] this is 250 times the amount installed prior to the Act. Prior to the act Germany was prominent in some renewable energy manufacturing (mainly wind); after the act Germany became the global leader in manufacturing and installation in wind, solar and biomass energy systems [48].

China: The renewable energy industry in china is the fastest growing in the world [49]. Chinese industry is particularly strong in the solar sector. Chinese low cost manufacturing has been one of the drivers for the rapid decline in PV system prices. China has been leading the solar thermal market for some time; China became the largest PV cell producer in 2008 [49]. Institutions and policies, National Renewable Energy Law, 2005; Medium and Long-Term Development Plan for Renewable Energy, 2007 were prepared. Concerning regulations and programs, The Renewable Energy Law identified four schemes to expand the market and industry for renewable [50]. Cost-sharing in which additional cost for renewable is paid by the user through a surcharge, Feed in Tariff: fixed additional amount is paid for renewable capacity on the grid, mandatory grid connection grid operators are obliged to purchase renewable electricity, national target sets target of 10% renewable by 2010 and 15% renewable by 2020, for rural areas China made significant government investment (US$ 293 million) to expand the market for renewable through its

Township Electrification Program (2002-2004)[51]. This program increased the market for PV in rural China. Another program, called the Golden Sun Demonstration Project, issued in 2009 aims to expand the market and manufacturing capability for PV through subsidies. The project subsidizes 50% of investment for solar power projects connected to grid and 70% of the investment for PV projects in off grid areas. Other forms of regulation for renewable include standards and mandatory regulations [51].

Bangladesh: Bangladesh is a low income country of 145 million people, 80% of whom live in rural areas [52]. Bangladeshis a good example of developing a PV sector in off-grid areas in a low income country. The Bangladesh PV program started in 2003 installed 650,000 solar home systems serving more than 2 million people, and employed more than 12,000 people by 2009. The program aims to increase installation to 2.2 million solar home systems by 2012 [53].The Bangladesh PV market was the fourth largest in the world in 2008 (after Germany, Japan and Spain).

Institutions and policies of Bangladesh; Infrastructure development support including for renewable energy is provided in Bangladesh by the Infrastructure Development Company (IDCOL). IDCOL is a government owned Investment Company established in 1997 and manages renewable energy programs in the solar, biogas and biomass areas [54].

Sector development support – The success of the Bangladesh PV program is attributed to the strong implementation capacity in IDCOL [54]. IDCOL and its partners have deployed a viable technology diffusion model which provides user and supplier financing, builds the technical capacity of user's and suppliers, and ensures quality or product and service [54]. Integration of supply of product and finance by a single company has put the burden of high quality service to users to the company thus ensuring the sustainable operation of systems as well as loan repayment. Another area where sector development has been useful was in setting up quality management system for PV products and services thus again ensuring sustainability.

Industry- The private companies and NGOs providing PV products and services have gradually increased their technical and financial capability to install and service systems through an extensive presence in most rural villages in Bangladesh. The market for PV system components was dominated by imports (China and India) in the early years. However, local manufacturing and assembly is now taking an increasing share of the market particularly for BOS components.

Five years after initiation of the program three of the companies' had started assembly of charge regulators. At the end of 2011 there was one PV module assembly plant in operation (5MW/a) and three others, each with capacity to produce 5MW/a, were under construction [54].

Regulations and sector development support open up the market and guide industry towards competitiveness. Regulations, in FiT, renewable purchase obligations and others, are the drivers for increasing the uptake of renewable on the off-grid/grid. Sector development support through technical capacity building and financing for users and suppliers, and monitoring for quality of products and services is the main instrument for uptake of renewable for off-grid applications. Regulations and sector development support are reviewed periodically to adjust to changing circumstances [54].

Therefore, from the above countries lesson concerning renewable energy, Ethiopia can learn the institutional and market arrangements for future dissemination practice and its stability.

2.6. Factors Affecting PV System performance

A. Irradiance

The fact is that irradiance varies throughout the day [55]. The angle of the sun, passing clouds, hazy weather, and air pollution can affect irradiance levels. However, the total energy received by the system from the sun remains relatively constant from year to year. Typically, energy from the sun only varies between 5-10% of the average in a given year. Consequently, quality solar energy output projections can be made based on the past years [55].

B. Shading

Shading has a surprisingly disproportionate impact on PV output. Shading may be caused by any obstructions in the vicinity of PV arrays that interfere with the solar window, especially obstructions to the east, south and west of an array [56]. This includes trees, towers, power lines, buildings and other structures, as well as obstructions close to and immediately around the array, such as antennas, chimneys, plumbing vents, dormer windows and event from other parts of the array itself. Shading of PV arrays can also be caused by accumulated soiling on the array surface, which can be particularly sever in more arid regions requiring regular cleaning to ensure maximum system output. For large PV systems with multiple parallel rows one in front of another in the array, one row of modules can shade the one in back if the rows are too closely spaced [56].

A simple rule for minimum spacing between rows is to allow a space equal to three times the height of the top of the row or obstruction in front of an array [57]. This rule applies to the spacing for any obstructions in front of an array. For example, if the height of an array is three (3) meter, the minimum separation distance should be nine (9) meter since the height of the adjacent row if it is three metera bove the front of the next row. However, even at the lowest altitudes the spacing should not be less than two times the height of the top of the adjacent module. Multiple rows of PV arrays can also be more closely spaced using lower tilt angles and event with the orientation penalty of a lesser tilt angle; it is usually a better option than to suffer shading losses [58].

C. Soiling

Dirty solar panels produce less electricity [59]. The term “soil-ing” sounds fancier than it is. All it refers to is dust, dirt, and other debris settling on the surface of the solar panels. This blocks sunlight from reaching the solar cells and reduces solar system performance [59]. In areas with frequent rain, soiling is not usually significant. Long periods of dry weather, such as East and the North east Ethiopia, experience more soil during the winter. Rapid soiling can also occur on systems located near construction sites and other places that produce dust. Cleaning the system may be undertaken to keep things looking nice, but it shouldn’t be necessary to maintain the expected energy cost-savings from a properly-designed system.

D. Array orientation

The orientation and tilt of a system impacts how much of the available irradiance the system can collect [60].PV arrays should be oriented toward the solar window to receive the maximum amount of solar radiation available at a site, at any time. The closer an array surface faces the sun throughout every day and over a year without being shaded, the more energy that system will produce, and the more cost-effective the PV system becomes with respect to alternative power options [61]. Similar to sun position, the orientation of PV arrays is defined by two angles called the azimuth and tilt angles.

E. The array azimuth angle:

Azimuth angle is the direction an array surface faces based on a compass heading or relative to due south [62]. North is 0^0 or 360^0, east is 90^0, south is 180^0 and west is 270^0. Unless side shading or local weather patterns dictate otherwise, the optimal azimuth angle for facing titled PV arrays is due south (180^0 compass heading) in the northern hemisphere, and due north in the southern hemisphere [62].

F. The array tilt angle:

Array tilt angle is the angel between the array surface and the horizontal plane. Generally, the higher the site latitude, the higher the optimal tilt angle will be to maximize solar energy gain [63]. A horizontal array has a zero degree tilt angle, and a vertical array has a 90^0tilt angle. The array azimuth angle has no significance for horizontal arrays, because they are always oriented horizontally no matter how they are rotated [63]. For unshaded locations, the maximum annual solar irradiance is received on a surface that faces due south, with a tilt angle slightly less than the local latitude. This is due to longer days and sun paths and generally sunnier skies during summer months, especially at temperate latitudes. Fall and winter performance can be enhanced by tilting arrays at angles greater than the local latitude, while spring and summer performance is enhanced by tilting arrays at angles lower than the local latitude. Adjustable tilt or sun tracking arrays can be used to increase the amount of solar energy received on a daily seasonal or annual basis, but have higher cost and complexity than fixed tilt arrays [63].Varying the array tilt angel results in significant seasonal differences in the amount of solar energy received, but has a smaller impact on the total annual solar energy received. For stand-alone PV systems installed at higher than tropical latitudes, the optimal tilt angle can significantly reduce the size and cost of the system required to meet a given load. The effects of non optimal array orientation are of particular interest to PV installers and customers, because many potential array locations, such as rooftops do not have optimal solar orientations [64]. When trade-offs are being made between orientation and aesthetics, having this information available can help the prospective owner and installer make decisions about the best possible array locations and their orientation. Multiplication factors can be used to adjust PV system annual energy production for various tilt angles relative to the orientation that achieves the maximum annual energy production, and are region specific. In fact, the amount of annual solar energy received varies little with small changes in the array azimuth and tilt angles [64].

G. Roof structure and condition

Installing PV panels onto roofs introduces hazards that can affect the structural integrity of the roof. Not only does the roof support the dead load of the PV system itself, but also external forces introduce structural loading. Outside installations exposes the PV system and roof assembly to hazardous elements [65]. Structural engineers must consider each of these loads separately and in combination to identify the worst-case loading situation. An important consideration for roof – mounted PV arrays is to assess the condition of the roofing system and determine whether the roof and its underlying structure can support the additional load [65]. Structural loads on buildings are due to the weight of building materials, equipment and workers, as well as contributions from outside forces like hydrostatic loads on foundations, wind etc. A structural engineer should be consulted if the roof structure is in question [66]. Generally, old house needs more rigorous inspection and tend to have more standard roof structures [66]. Wind loads are a primary concern for PV arrays, especially in desert prone regions like north east and east part of Ethiopia. While common standoff PV arrays do not generally contribute to any additional wind loads on a structure, the array attachment points to the structure or founding must be of sufficient strength to withstand the design loads [67].

H. Balance of system locations

This includes all the wiring, fuses, and combiners, fittings, grounding connections, switchgear, and metering [68]. Any site survey also includes identifying proposed locations for all balance of system components, including inverters, disconnects, over current devices, charge controllers, batteries, junction boxes, raceways, conductors and any other electrical apparatus or mechanical equipment associated with the system. The PV installer must ensure that all equipment locations are suitable for the intended equipment [69].Considerations for balance of system locations include providing for accessibility to the equipment for installation and maintenance [70]. All electrical equipment must be properly protected from the environment unless the equipment has applicable ratings [71]. Some equipment has special considerations, covered under different sections of the electrical and in manufacturer's instructions. For example battery locations should be protected from extreme cold, which reduces their available capacity [72].

I. Latitude of Ethiopia

Ethiopia has an intense climate with typical seasonal rhythm strongly marked in respect of temperature, rainfall and weather generally [73]. Cold, rainy summers from June to August and hot, dry winter from December to February are separated by autumn (September to November) and spring (March to May) seasons of rapid change in weather conditions [73]. The land surface of the country can be divided into the highlands of mountainous areas and low lying areas [74]. Regarding air temperature, Ethiopia has a cold summer and mild winter [74]. Fog is infrequent and usually confined in summer in early mornings, but there are long periods in the mountainous areas. Visibility is generally very good; however, during the summer season the sky is not much clear. Finally, all parts of Ethiopia enjoy a very sunny climate compared with most countries. According to world atlas the tropic of cancer and Capricorn is at the latitude of 23.5^0 norths and south of the equator separately [75]. The sun moves to the tropic of Capricorn on December 21st, and to the tropic of cancer on Jun 21st [75]. Ethiopia is located in the range of Latitude between 5^0 and 15^0. Therefore, the sun is at southern sky above the land of Ethiopia during the three months before and after December 21st, six months in total, and at northern sky during the two months before and after June 21st, four months in total [76].

Source- world Atlas.htm

Figure 2.1 Ethiopia Latitude and Longitude locations

Therefore, this study mainly tries to scrutinize the solar energy dissemination practice and orientation effects in providing energy thereby can be optimized to get the maximum energy output from the systems.

CHAPTER - THREE

3. Method

This study investigates the PV system dissemination, orientation installation, system performance and the socioeconomic benefit obtained from the system in the rural area of Ethiopia. The study was planned to be conducted using techniques such as desk review, key informant interview and on site survey. The site survey aspires to examine the manners of PV installation, customer's level of awareness and collection of key measured data's regarding the performance of the selected systems. But during the process of this study since most institutional systems are installed in remote regions, making the possibility of taking measurements difficult due to the required finance and time. At the same time, since the SHS systems are sealed, measuring component performances was prohibited due to guarantee limitations provided to the customer's. Thus, the site survey simply focuses on performing observational survey of the installation and an interview with the customer's regarding their level of satisfaction and awareness. The survey was performed in the four major regions, i.e., Amhara, Oromia, SNNPR and Tigray. Luckily, the required performance measurement data for the institutional systems were obtained from the Ministry of Water, Irrigation and Electricity. The obtained data's include voltage out-put measurement of PV panel, inverter, charge controller and the battery. However, since this data were collected at the end of 2014.

3.1. Survey area

While desk reviews and other interview activities evaluate national issues. The site survey must be performed at selected location for logistical reason, specifically to reduce time and financial requirement. Thus the survey area focuses on selected villages in four regional states, Oromia, SNNPR, Amahara and Tigray. In each regional state, the corresponding zonal bureau was also involved during focus group discussion in the selected study areas. The selected villages are Mukeyeharo from Oromia, Dilagumbe from SNNPR, Adama Kebele from Amhara, and Adi-mehameday from Tigrai are the selected. The selection was made purposely, to reduce time and money required to do the survey. This selection was made after several desk reviews and informal and an informal discussion regarding the issue was performed. From that work the overall observation from the four villages would reflect the dissemination and installation challenges observed in the hosting woredas. Figure 3.1 to 3.4 shows an approximate location of the village the hosting woreda.

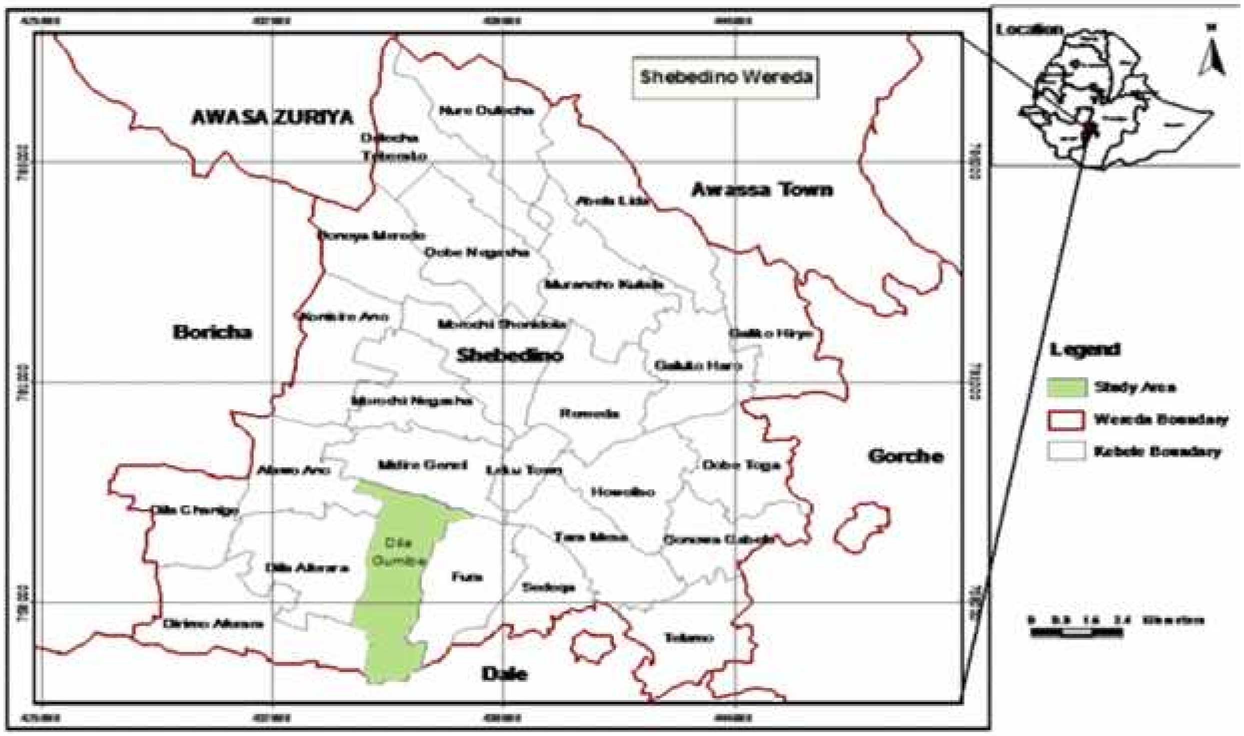


Figure 3.1 Map of shebedino weredaDillagumbe kebele

Figure 3.2 Map of Minjar-shenkora wereda Adama kebele

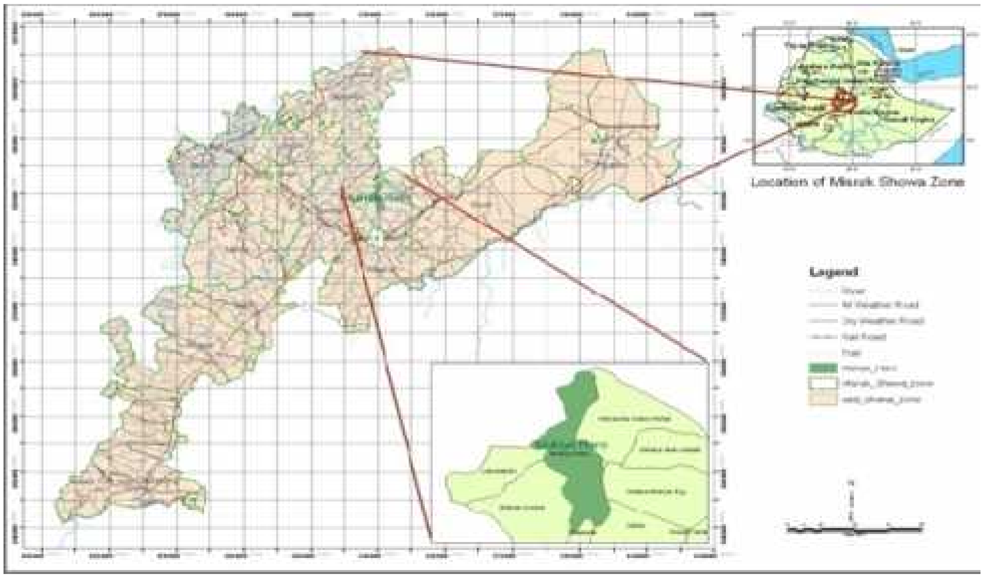


Figure3.3 Map of east shoa zone Mukiyeharo kebele

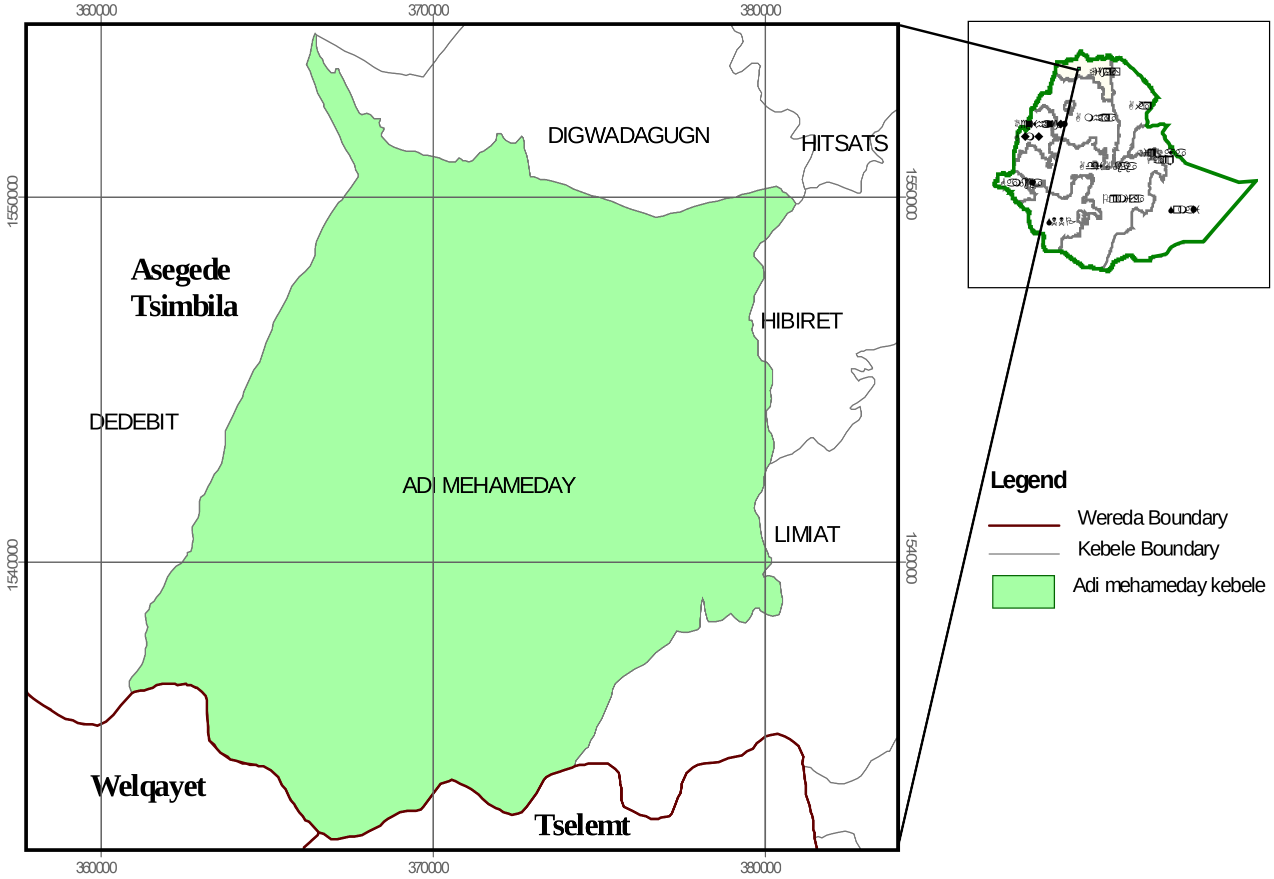


Figure 3.4 Map of Asgedetsimbla wereda Adi- mehameday kebele.

3.2. Approaches as related to disseminated system

The ministry of water irrigation and electricity of Ethiopia disseminates two types of systems which were broadly categorized as home system and institutional system. SHS systems disseminated in all regions Ethiopia are 9 types, all differing only in system sizes, namely 8W, 10W, 20W, 40W, 60W, 75W, 80W, 100W and 130W. The institutional systems are of two types i.e., 300W for Primary school and 600W for health post (HP). As indicated above, no measurement data were collected on SHS systems but reviewed literatures and observations show that all SHS systems were functioning at the time of the study. Thus, studies performed on the SHS relates to examining their installation, customer awareness and use as well as other barriers towards its adoption. But several failures were reported on the institutional systems, as a result obtained measurement data's were used to identify types of the failures. This secondary data contains voltage output of inverter, PV module, Battery and the charge controller, typical measurements useful to identify component wise. The measured data's are of health post systems installed by MoWIE. That study also did survey system installation orientation. The detail of the measurement and the obtained result is presented in Table 3.1.The study units were health posts (HP) since there is no secondary data for school PV system in relation to the above system components, and for the examining of orientation installation the study units were primary schools this also used because the inspection conducted by the ministry of water, irrigation and electricity only done for orientation and system component installation problems examining purpose. The measurements were made on systems installed at sidama and Hadiya zone of SNNPR, and North West and Central zone of Tigray regions.

Table3.1 Inspection area, component voltage output and System status for health post

No	**Region**	**Zone**	**Woreda**	**Name of health post**	**Battery voltage output**	**Charge controller voltage output**	**Inverter voltage output**	**PV voltage output**	**System status**
1	SNNPR	Sidama	Arbegona	Charicho	4.9V	0V	0v	19.2V	Non Functional
2	SNNPR	Sidama	Arbegona	ArbegonaShashoncho	4.51V	0V	0V	19.2V	Non Functional
3	SNNPR	Sidama	LakaAbeya	AbeyaZuria	0v	0v	Inverter burnt	Wires are disconnected	Non Functional
4	SNNPR	Sidama	AletaWondo	KilaHikicha	0v	0v	0v	19.3V	Nonfunction

									al
5	SNNPR	Sidama	HawasaZuria	JaraHinesa	0v	0v	0v	19.5V	Functional
6	SNNPR	Sidama	Chuko	Gambella	0v	0v	0v	19.5V	Not functional
7	SNNPR	Sidama	Bensa	Osole	3.75V	0V	0V	0v	Not functional
8	SNNPR	Sidama	Hula	Hula Bochesa	4.67V	4.67V	0V	19.5V	Not functional
9	SNNPR	Hadiya	West Badewacho	Hawora health center	11.26V	11.5 V	235V,	Not measured	Functional
10	SNNPR	Hadiya	East Badewacho	Tikareqoqore	13.9V	11.4V	232V	19.2V	Functional
11	Tigrai	central	Merebleke	Adifetaw	13.55V	11.6V	0V(fuse burnet)	19.96V	Not Functional
12	Tigrai	central	Ahferom	MayiHamato	13.53V	11.2V	231V	19.08V	Functional
13	Tigrai	central	Wereileke	Golagule	13.72V	11.5V	229V	19.68V	Functional
14	Tigrai	central	Merebleke	Tarewer	13.76V	11.7V	222V	19.85V	Functional
15	Tigrai	central	Naideradiat	Teregegn	13.73V	11.3V	235V	19.28V	Functional
16	Tigrai	central	KollaTemben	Dedere	13.53V	11.6V	231V	19.08V	Functional
17	Tigrai	North west	LalayAdiabo	Adimillion	12.23V	11.6V	242V	16.12V	Functional
18	Tigrai	North west	LalayAdiab	AdiNigisti	13.12V	11.6V	201V	18.5V	Functional
19	Tigrai	North west	AsgedeTsembela	Maebele	13.79V	11.2V	242V	19.41V	Functional
20	Tigrai	North west	Tatayadiabo	Lese	12.89V	11.5V	223V	19.08V	Functional
21	Tigrai	North west	Tselemti	Chachare	12.03V	11.7V	223V	19.07V	Functional
22	Tigrai	North west	Tselemti	Fiyelwuha	13.75V	11.3V	229V	18.82V	Functional

The following gives the summary of the materials and techniques that have been used during the study. A number of tools, measuring devices/equipment and safety gear were used for conducting the site survey. As given in Table3.2.

Table3.2 List of tools used for measurements of the outputparameters

S.No	Type	Purpose	Remark
1	GPS	To obtain coordinate and make a location map	Obtained from MoWIE
2	Laptop(electronic notebooks),	Record and store data and report preparation	Obtained from MoWIE
3	Camera	To take picture	Obtained from researcher
4	Calculator	To conduct calculations	Obtained from MoWIE
5	Multimetr	To measure voltage output of PV module, inverter, and charge controller	Obtained from MoWIE
6	Hardhats, safety glasses, safety shoes, gloves.	personal protective equipments	Obtained from MoWIE
7	Basic hand tools	Contingency	Obtained from MoWIE
8	Tape measures	To measure distance	Obtained from MoWIE
9	compasses levels	To determine direction	Obtained from MoWIE
10	Protractor	To measure angle	Obtained from MoWIE

Figure 3.5 Taking measurements during the field survey

3.3. Data collection Method

Desk review

The purposes of the desk review were to synthesis relevant information about dissemination strategies, technical and social aspect of dissemination challenges, and to identify gaps of solar home and institutional systems. For these purposes, an intensive literature review, and review of all relevant documents were done. The documents that were reviewed include various government reports, policy and regulatory documents, and published related international scientific reports and peer-reviewed publications. The reviews were focused on comparing the local strategy with international best practices in order to find proper solutions for local challenges.

Observation

The observation targets are mainly on array location possibilities and overall PV installation orientation. The observation was regarding panel location and orientation, SHS cabinet position. To collect this information semi structured checklists were used (See annex1-11).

1. Key informant interview

To find information about current status about solar home dissemination, installation understanding of the system, their attitude towards repaying debt and availability of local supply or spare part/access to maintenance technicians, relevant institutions key personnel and customer’s were interviewed. The interviewed institutions were federal, regional, zonal and wereda mines and energy office, kebele administration and kebele level solar cooperatives, cooperative organization and the interview.

Data analysis and interpretation

The data that were collected from the study by using the above technique were analyzed by comparing the dissemination target against the real dissemination achieved by the government to know the success. The measurement and observation results were used to identify typical cause of system failures and the presence of consistent procedures regarding the installation orientation.

Modeling the impact of PV orientation:

It was also examined the optimal orientation installation in five selected areas of Ethiopia. To examine the PV orientation impact, PVsyst software were used to identify the tilt and azimuth angle for better PV generation and can give an accurate evaluation of solar photovoltaic panels energy output. The software is mainly designed to study on stand alone, grid connected and solar pumping PV systems for sizing, simulation and data analysis and to be used by energy professionals, architects, engineer, and researchers. It is also a very useful educational tool particularly in the solar energy research this makes PVsyst preferable than other software. It includes a detailed contextual help menu that explains the procedures and models that are used, and offers a user-friendly approach with guide to develop a project. The PVsyst helps greatly in identifying better tilt and azimuth angel. The software performs this first by importing meteo data from many different sources such as from Meteonorm WRDC data (World Radiation Data Center), NASA-SSE Data (Surface Meteorological and Solar Energy Programme), PVGIS-ESRA, and Helioclim-1 stations. Afterwards, by using these data the PVsyst determine the optimized solar irradiance intensity for different geographical location with respect to correct tilt and azimuth angle.

I. Meteorological data sources of PVsyst

Meteonorm monthly irradiance data are available for about 1,200 world wide "stations", as averages of 1960-today). All "stations" (i.e. with irradiance measurements) of the main European and African countries are referenced in the PVsyst data base.

WRDC Data (World Radiation Data Center) provides monthly irradiance for 1195 sites in the world, averaged during periods between 1964 up to today. These data don't include temperatures, which should be obtained from another mean.

·NASA-SSE Data (Surface Meteorological and Solar Energy Programme) hold satellite monthly data for a grid of 1°x1° (111 km) covering the whole world.

PVGIS-ESRA Data give monthly values interpolated for any geographical location from average of 1981-1990 terrestrial measurements for Europe, and satellite 1985-2004 data (METEOSAT) for Africa.

Helioclim-1 is satellite data from METEOSAT, given for each year 1985-2005 independently for Europe and Africa.

Ret screen is a Canadian software which holds a complete database for any location in the world, optimized for using the best available data at each location from about 20 sources, the main ones being the WRDC and the NASA irradiance data. Temperature and wind velocities are also provided probably with good reliability.

All these monthly data are imported as geographical sites requires the construction of synthetic general hourly data files for being used in the simulation. Monthly values are often given as averages over several years.

II. Basic Approach of PVsyst Software and General Procedure

- ✓ Create a project by specifying the geographical location and the meteorological data.
- ✓ Define a basic system variant, including the orientation of the PV modules.
- ✓ The project’s site defines the coordinates (Latitude, Longitude, Altitude and Time zone), and contains monthly meteorological data.
- ✓ The simulation will be based on a meteo file with monthly data.
- ✓ Set the correct values for tilt and azimuth of the specified location then simulate the orientation.
- ✓ Identify at which tilt and azimuth angle the maximum irradiance is found.
- ✓ Compare the result in each azimuth with the MoWIE's azimuth and tilt angle recommendation for installation.
- ✓ Determine irradiance difference in percentage according to the result generated from the software.
- ✓ Determine the location of the sun (sun path) at different seasons.
- ✓ Decide the possible orientation of the panel in all the four seasons in Ethiopia. Finally based on orientation possibility and impact on the energy output of solar PV is also discussed depending on the modeling results.

CHAPTER-FOUR

4. RESULT AND DISCUSSION

4.1. Disseminated solar PV system type and geographic location in Ethiopia

This study examined the dissemination issues of SHS systems and institutional systems installed by the support of the Ministry of Water, Irrigation and Electricity. The following provides the manner of their geographic distribution.

4.1.1 Solar Home System types distributed in Ethiopia

The solar home system (SHS) distributed in Ethiopia falls in to the two major categories, namely alternative current (AC) (which has an inverter to do the DC to AC conversion) and direct current (DC) supply systems type. The single circuit diagram for both systems is given in figure 4.1 and 4.2. These systems were distributed to rural areas where grid electricity is not accessible.

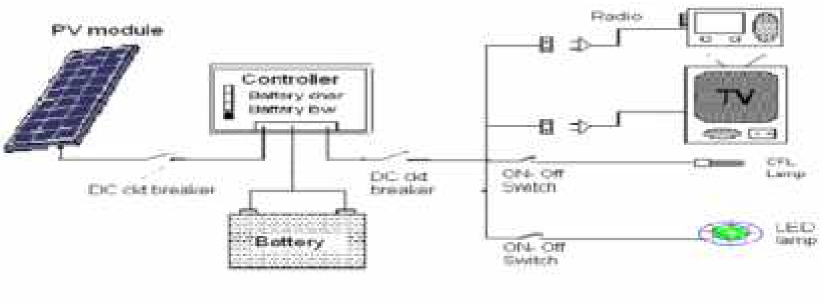


Figure 4.1 Circuit diagram of DC system type

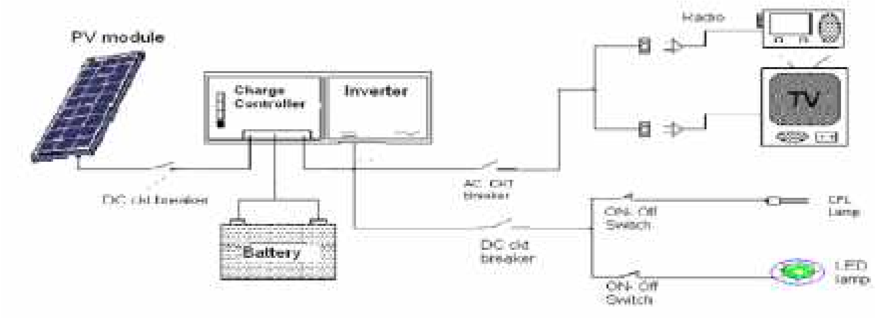


Figure 4.2 Circuit diagram of AC system type

As shown in figure 4.1, the DC system has no inverter it has only crystalline module with complete module mount structure and tilt adjustment, charge controller and battery gel, with well ventilated box. DC circuit breaker is installed between the PV module, the charge controller and the electronic devices. On the other hand, the AC type system figure 4.2main components are, the crystalline module with complete module mount structure and tilt adjustment, gel battery with well ventilated box, charge controller, pure sine wave inverter, dc LED lamp with holder and on-off switch, different size of circuit breakers, dc to dc voltage converter from 12v dc into option to use 3, 4.5, 6, 7.5 and 9 V dc, AC socket outlet, dc mobile charging and socket with different pin plug (for different mobile model)(See annex, Table A).

Figure 4.3 shows the geographic location of disseminated solar home systems. Accordingly, the majorities (11,570) were distributed in Oromia, 7,161 and 5,678 were distributed in SNNPR and Amhara regions, respectively. The reason for the highest number of distribution in these regions were because they do have organized solar cooperatives and allocated a matching fund which is a prerequisite to get the provision of SHS. With the exception of Addis Ababa, which highly electrified population, all the other regions poor performance were related to their ability to meet the requirement. The past five years have seen very rapid take-up of SHS in rural areas, with several units sold annually. Despite the accelerating SHS dissemination rate, there is still a significant gap between SHS supply and potential SHS demand due to the growing number of households and rising incomes. Assuming a distribution rate of SHS of approximately 0.3 million per annum each and population growth of 2.5% (and thus an increase in the number of rural households of approximately 0.3 million/year), the current dissemination rates are barely able to cover just the population increase. Moreover, the 2011–2015 GTP of the MoWIE targets to disseminate153,000 SHSs across all regions however, only 28,735 SHS were distributed resulting in a significant gap between the target and the achievement.

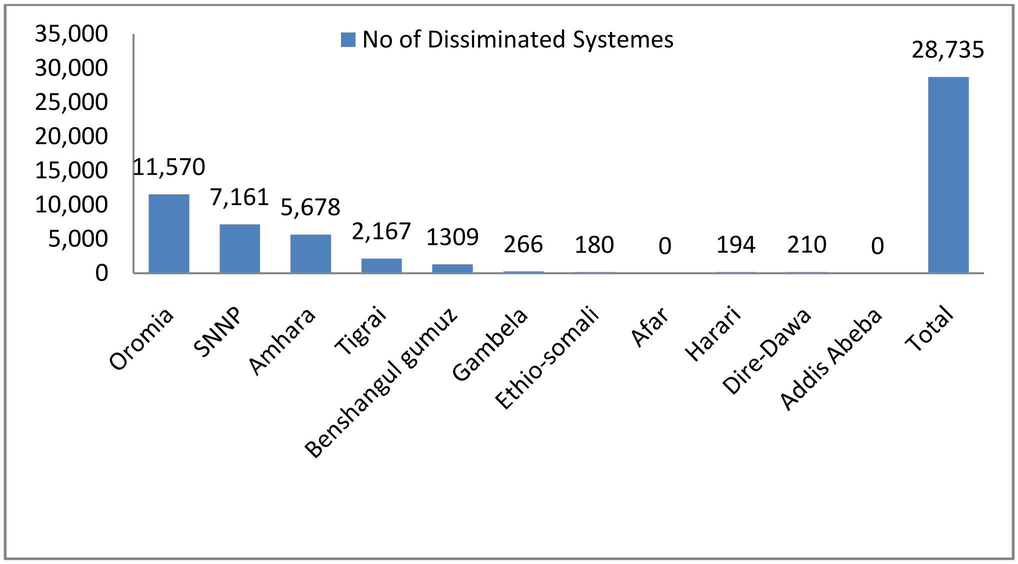


Figure 4.3 Geographic locations of SHS

4.1. 2. Institutional PV System types distributed in Ethiopia

The institutional systems installed by MoWIE in all regions are mainly of two types 300Wp and 600Wp for the primary schools and health post respectively. The institutional PV systems are bigger in size and power capacity than the households (Figure 4.4). This is because of the required high power in order to run various appliances installed in the respective institutions. All institutional PV systems are AC type systems.

Figure 4.4 The size of institutional PV system

The geographic distribution of disseminated institutional PV systems is summarized in Figure 4.5. The figure shows, a total of 345 systems were installed at health posts distributed throughout the country, with 115 of them being installed in Oromia region. The figure also shows that a total of 270 primary schools were distributed in all regions. According to the interview with MoWIE representative the number of systems to be distributed was determined based on the regional energy offices request. The other requirement to get the services at health post level is that the surrounding communities should not electrified, and will not be able to receive grid electricity services within the next 3 years given that the health post is operational and equipped with basic medical equipment. While the federal government distributed a number of systems it planned to install at health posts. Comparing to the number of health posts that needed the system, their plan was not even close to the demand. The health posts receiving the systems are insignificant(345 systems) when it is compare with the available number of health posts in the country, which reached 16,048 in 2005/2006 EFY, majority of which are in rural Ethiopia. It was indicated that some health posts in hot rural areas are reporting the loss of medical materials that requires refrigeration. Similarly, the dissemination of the school systems is not close to the demand (estimated based on the 30,534 schools that needed the facility). Moreover, interview with MoWIE and regional energy representative result show that, the distribution focuses on applying some national standards instead of providing proper system suitable to local weather conditions.

In summary, results presented regarding the dissemination of both SHS and institutional system dissemination shows that the dissemination is significantly lower than the demand. It may actually be better to state that PV technology is one of the least utilized in Ethiopian market despite its promising potential. This could be attributed to several problems that will discuss below.

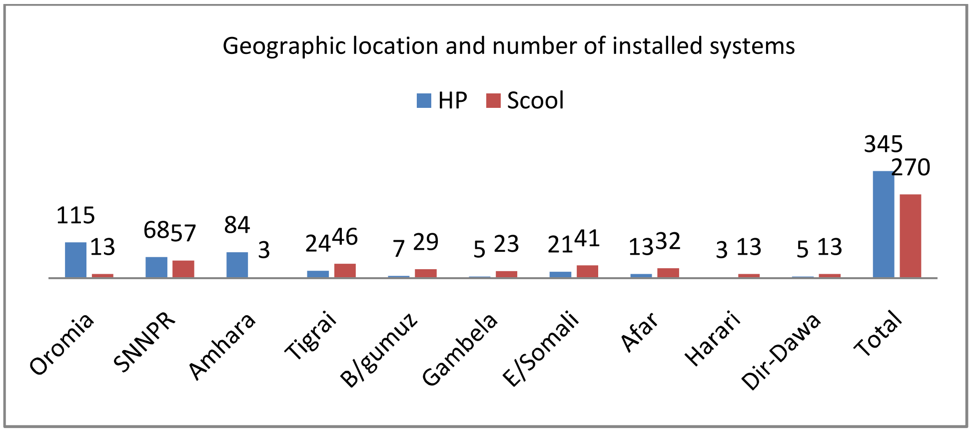


Figure 4.5 Insititutional PV system distributions byregion

4. 2. Dissemination problems:

Sections from 4.2.1-4.2.7 clearly showed that the dissemination of PV technology and its use in rural Ethiopia is very poor. The following subsections (4.2.1-4.2.7) are the main challenges of PV dissemination. These are identified through measured data, field survey, document review and interviews with key informant personnel.

4.2.1. System failures and other technical problems

According to MoWIE inspection field report, system failure was not reported for SHS. The rare reported cases in SHS failure were associated to long shelf time of the component, which was blamed for the identified battery failure. However, significant failures were reported for institutional systems. From the total systems inspected and presented in Table 3.1 (Chapter 3), 40% were found to be non-functional. As shown inTable3.1, the battery voltage corresponding to the majority of the failed systems (8 out of 9) are very low (0V-4.9V) as opposed to reported high battery voltage corresponding to the remaining systems. Low battery voltage shows that either the battery is dead or its input to the battery was zero or probably battery interconnection cable is loose. The input will only be zero when the charge controller is not functioning or there is no input from the module. But it is observed that all the module output is at good conditions except system No. 3 and 7. For system No 3 and 7, cable of the module is disconnected. The rest of the systems have no problem with the module voltage output.

The major failure in the other cases seems to arise from non-functional charge controller, which in turn leads to the battery failure. All the other batteries are in normal operation. The zero output measured at the output terminal of the inverter is simply because of the absence of power input as can be seen from the battery voltage and the charge controller output.

The representative from MoWIE, Rural Electrification Fund stated that, the replacement of failed components took months. Even after replacing the failed components such as charge controllers, the system did not function. This may be because the battery has already failed due to long replacement time and over discharging that occurred. This slow response of the PV industry has negative impact on customer satisfaction and service delivery of the institution. One of the major reasons for the sluggish response is the dependence of the PV component supply on the government bureaucracy than a competitive market.

4.2.2. Availability of replacement and maintenance

At present, most government based projects such as the 28,735 SHS installed by MoWIE are purchased by announcing international bid at federal level. This affects domestic companies not to compute with them because of their low resource capacity. The purchased equipments are sent to regions for installation, which was done by a single company that entered into a contract with federal government. This has caused significant problems. The interview with end users in the four study area reveals that, customers have the difficulty to find technicians, replacement components and maintenance services. As a result, even functioning SHS's that have some failed lamps did not know where to find the proper replacement. As discussed in section 4.2.1 some failed components (such as charge controller) may have caused further damage to key components such as batteries due to prolonged replacement time. This all shows the importance of the government's role in creating the market than running it.

In agreement with this finding, REF (2016) report has acknowledged that PV dissemination would experience significant delivery challenges if maintenance and availability of spare parts continues to become a problem.

4.2.3. Regulatory and Institutional problems (the implementing body)

The result from desk review reveled that a key issue concerning the National Energy Policy of Ethiopia is that there is no authority or agency responsible for introducing rural energy initiatives other than for expanded grid electricity and petroleum products. In addition, the Climate Resilient Green Economy (CRGE) strategy for Ethiopia is mainly focused on expanding utility-scale electricity generation and extending the grid. There is no national regulatory and legislative framework for solar energy for the rural sector and no incentives to specifically promote and encourage solar energy for rural populations. In addition, there is no legislation or regulations currently enacted which provide up-to-date technical standards for small-scale solar PV technologies. Development of standards for rural energy technologies (RETs) is therefore vital and needs stronger emphasis by the government.

The Rural Electrification Fund (REF) of MoWIE, with a capitalization of under USD 2 million and limited capacity, does not have the ability to finance a large number of small-scale solar energy projects. It is important to strengthen the institutional capacity of MoWIE's Alternative

Energy Technology Development and Promotion Directorate (AETDPD) and of the REF to promote solar PV to rural communities and to develop and enforce relevant policies and regulations. Furthermore, it also vital to remove barriers that hamper the wide-scale use solar PV technologies in households and productive uses in rural areas of Ethiopia, where extending the grid is simply not feasible in the short-run and where the ability to pay for larger scale solutions is often limited, strengthened regulatory and legal framework based on national standards, rural public awareness campaign on solar PV technologies by using different mechanisms such as road-shows, exhibitions during public and government holidays, weekends, sustainable financial mechanism (SFM) for rural households and business incubator to promote greater entrepreneurship for investment in solar PV can enhance the utilization of solar technologies at rural areas. In addition, ensuring product quality is a key concern and should stressed by all relevant stakeholders (Ministries and Government agencies, development partners, solar enterprises, the Ethiopian customs service, importers, distributors and retailers) must collectively play to prevent poor-quality or inferior products reaching consumers and to strengthen the integrity of the market. Miss labeling of imported products in particular has led to past product underperformance and failure in the marketplace thereby leading to limited distribution of the system.

4.2.4. Tariff issues

The result from desk review revealed that, in Ethiopia solar provision tariff is not yet implemented. It is just distributed at household level by the government and private sectors without any tariff to be paid. However, Feed-in tariff (FIT/FiT), standard offer contract, advanced solar tariff, or solar energy payments is a policy mechanism designed to accelerate investment in solar energy technologies across the world. It achieves this by offering long-term contracts to solar energy producers, typically based on the cost of generation of the technology rather than pay an equal amount for any type energy source.

In addition, feed-in tariffs often include "tariff digression", a mechanism according to which the price (or tariff) ratchets down over time. This is done in order to track and encourage technological cost reductions. The goal of feed-in tariffs is to offer cost-based compensation to solar energy producers, providing price certainty and long-term contracts that help finance for solar energy investments.

4.2.5. Market issues

There are three categories of consumers viz households, small businesses and institutions including schools, health centers, and telecom and signaling. High demand in off-grid areas for lighting and mobile charging as companies are expanding their markets, supply chains independently with some retail outlets in major towns, new entrants/larger players are emerging in the market and also due to active promotion by private sector agents and development bodies in the target market areas. However there are also challenges found during the study these are, absence of local producers, goods are imported from abroad, high costs of products, high costs of setting up retail outlets in target markets (i.e., off-grid communities).

Dominating the off-grid market are project-based supplies with fewer companies working with lack of service companies (installers and service providers), lack of industry accountability to customers for products and services rendered, there are no government regulations and industry guidelines for self-regulation this often leads to distrust among end-users when products breakdown after short periods of use, the policies and regulatory environment are generally supportive but unaccompanied with specific strategies, regulations and investment plans to ensure scaling up (e.g., Feed-in-tariff have been promised but never realized). However sustainable market requires, availability of local producers, development and enforcement of appropriate product and technology standards, consumer education on product quality assurance, publicizing minimum standards among stakeholders, enforcement of warrant certificates and after sales services, assisting development of supply chains, developing varied financing mechanisms for consumers, opportunities of lowering product costs by assessing the margins, FOB costs, freight charges, and taxes/duties. Thereby improvements in the above-mentioned issues advance the dissemination of PV systems across the country in large scale.

4.2.5.1 Cost issue

Cost is one of the most important factors that determined the dissemination of solar system.

According to pvXchange, the world’s largest brand-independent marketplace for solar modules a monthly index of 2016 of wholesale prices for crystalline PV module is presents in Table 4.1.

Table 4.1 International monthly solar PV price of 2016

Country	**Monthly Price** / Wp ($)								**Average Price**
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**Jul**	**Aug**	
Germany, Europe	0.66	0.65	0.64	0.64	0.63	0.63	0.62	0.61	0.635
Japan, Korea	0.74	0.73	0.71	0.72	0.71	0.7	0.69	0.69	0.711
China	0.63	0.62	0.62	0.62	0.61	0.6	0.59	0.58	0.608
S.E.Asia, Taiwan	0.54	0.55	0.55	0.54	0.54	0.54	0.54	0.53	0.541

Source:PVX spot market price index solar PV modules

In an overall, module prices generally declined internationally. Prices for European and Chinese modules were in a neck-and-neck race to the bottom, and even reached a low for the year. The major key point that determines the price is product quality, which also depends on origin. If the origin is unknown, judging quality is reduced to a crapshoot. Buyers who do not check these theme selves, but instead trust manufacturers' guarantees, are naive. So many apparently solid producers have already overstepped boundaries, making their warranties worth little more than the paper they are printed on. Even random testing of every delivery has failed to protect buyers from surprises. Nevertheless, meticulous visual inspections and performance testing at least provide a minimal measure of assurance. Prices for modules from Germany, Europe, Japan and Korea, as well as those from Chinese factories, are slowly converging toward the level of Southeast Asian module price. The reason for the relative low price in Southeast Asian is due to high population number in the rural areas which creates high demand of solar PV modules. The price per watt experience in Ethiopia is quite different from the rest of the world. Where the price is set based on the system size and it differs from system size to size. For example the price for 8W is 24.26 $/W however the price for 60W is 7.94 $/W.

4.2.6. Public awareness

It was also observed that the public has varying views of the technology. Customers with functioning systems express positive views of the technology. In the contrary, in cases where some components have failed, customers have demonstrated negative attitude towards the technology. For example, in Adama Kebele of the Amhara region, failure in USB components of the SHS used for mobile charging has produced a negative reaction from customer. This underlines the importance of delivering the promised services without any compromise. It is also important to give the necessary information about the systems advantage and disadvantage. The interview with Sidama zone, Minjar-shenkora and Adama wereda's energy representatives revealed that, customers are received their systems without enough awareness. This results varieties of complaints towards the program, including complaint over delayed installation, lack of access to maintenance services, high price, etc. As a result, some customer's have stopped paying their monthly loan to DBE. In general, to lead the PV industry to a success creating tailor-made trainings given to various stake holders will be necessary, together with a control over the quality of the technology in the market.

4.3. The Impact of PV based electrification and its social benefit

To determine the impact of PV based rural electrification and its social benefit focus group discussion (FGD) viz on community elders, students and women's were conducted. In addition, key informant interview and observation were made on those particular four study kebeles. The result obtained indicate that most of the focus group participants were happy with the system for the reason that they be able to charge there mobile phone, watch television, for worshiping and clean electricity light, we observed that many of them were surprised when electricity is coming from solar energy. They were pleased in that their life style is becoming modern and plausible about the system in that their main problems particularly their illness caused by traditional lighting using kerosene has been reduced. They also responded that unlike kerosene lamp, it gives high quality light. The electricity that comes from the solar PV is also advantageous in terms of safety in that fire hazards that came from using kerosene lamp has been avoided. Moreover, during our FGD it was boldly expressed that there were people that lost their lives and properties due to such accidents. The interview result also showed that the solar PV based rural electrification in off-grid village in the four study area's solved many problems and changes the lifestyle of the village residents. It is also expressed that, the presence of modern lighting system increases working hours of residents and be able to use electrical equipments such as CFL or LED lamps that have higher luminous and helped students to study and perform their homework at night. According to the FGD participant's point of view the electrification also played a great role in expanding communication and entertainment services as shown in Figure 4.8 by providing electricity for radio/tape, TV and even some amplifiers for preach at Emanuel churches in Shebedino wereda. These create, access to educational program which can improve their life style. Access to PV system in rural areas increase learning opportunities for children, increase household welfare through better child and home care, increased income opportunities for households and enterprises, improved connectivity (mobile phones) and access to information (audio-visual). Added advantages include removal of indoor air pollution from the home.

Figure 4.6 Benefits of PV and FGD photos at the study areas, (photo taken by researcher 2016)

4.4. Comparison with other country solar programs

In order to evaluate the performance of Ethiopia's solar program it is crucial to compare against other countries solar program experience. Accordingly this study tries to compare Ethiopia's solar energy program with that of Bangladesh, China and Germany the reason for selecting this countries experience was they have succeeded in there solar program implementation in a more sustainable way. The main parameter that was used to compare were, the implementer, activities performed by implementer, key success factor of the program and number of installed systems (Table 4.2)

Table 4.2 Comparison of Ethiopian solar program with other countries

Country	Implementer	Activities performed by implementer	Key success factor of the program	Number of installed systems
Bangladesh	Public private partnership	Sell, install and service	Strict quality management, subsidies to distributors as well as consumers, consumer loans through the distributors, in the supply chain through small and large suppliers.	2.2 million SHS
China	National energy administration ,	Sell, install and service	Institutions and policies, national renewable energy law, medium and long-term development plan for renewable energy, cost-sharing, feed in tariff and	35.78GW

	privatesectors.		mandatory grid connection,	
Germany	Government and private company	Sell, install and service.	Introducing FiT law in 1991, Act of Renewable Energy Resources in 2000, promotion of energy security, climate sustainability, domestic industry, jobs and innovation, regulations subsidy policy.	24GW
Ethiopia	Government	Sell, install and service (inadequate)	No	29,350 SHS

As it is depicted in Table 4.2 Ethiopia's solar program run in unsound way as it is compared with Germany, Bangladesh and china. Because, unlike them where the implementer are public private partnership, in Ethiopia the implementers is government in a project based which leads to the poor participation of the private sector thereby decrease dissemination, sell, service and installation activities are also inadequate as compared to those countries because there are not enough suppliers, installers and trained personnel to service if any maintenance is required in addition Ethiopia do not designed and committed to promote solar program activities through various intervention which could lead to success of the program for example, like in other counties mentioned in Table 4.2 where there is strict quality management, subsidies to distributors as well as consumers, consumer loans through the distributors, in the supply chain through small and large suppliers, policies, national renewable energy law, medium and long-term development plan for renewable energy, cost-sharing however there are slight initiatives in Ethiopia.

4.5. Observed PV orientation in the existing installations.

The orientation and tilt of a system impacts how much of the available irradiance the system can collect. To study the orientation scenario of solar panel in the study area a total of 20 solar home systems were observed in the four study kebeles in each 5, in addition inspection field report of MoWIE is reviewed. As it is depicted in Table 4.3all (20) the solar home system fall in 0^0-5^0 orientation, meaning they are in a horizontal tilt angle.

Table 4.3 Tilt angle difference from the horizontal

No	Name of kebele	Region	Observed solar system orientation (Tilt and azimuth)		
			0^0-5^0(in number)	6^0-10^0(in number)	11^0-15^0(in number)
1	Dilagumbeye	SNNPR	5	0	0
2	Mukeyeharo	Oromia	5	0	0
3	Adama	Amhara	5	0	0
4	Adimehameday	Tigrai	5	0	0

As shown in Figure 4.9 the tilt and orientation of the PV panel installed in all the household is not oriented toward the solar window to receive the maximum amount of solar radiation. PV arrays should be oriented towards the solar window to receive the maximum amount of solar radiation available at a site at any time. The closer an array surface faces the sun throughout every day and over a year without being shaded, the more energy that system will produce, and the more cost-effective the PV system becomes with respect to alternative power options. According to world atlas, Ethiopia is located in the range of latitude between 5^0 and 15^0. Which implies the panel orientation also should be in this range to get the optimum irradiance at all location for any system type. Nevertheless, in this study the majority (20) are in horizontal tilt angle which shows systems installed in the study area are not correctly installed thereby giving low amount of energy against the required amount.


Photo taken by researcher2016

Figure 4.7PV arrays should be oriented toward the solar window

At the same time, the institutional systems installed at a school and health post in Dilagumbe village, which was installed by plan-Ethiopia (non-governmental organization), has a tilt angle of about 25^0 and the installation was also seen to fall short of the basic principle of solar installation since some of the institutional and the SHS modules were under a shadow of nearby trees. See Figure 4.8.

Photo taken by Dr Abebe S. 2016

Figure 4.8 Shadow on PV system from surroundings

During the field survey, the shadowing effect could have been simply avoided had the installer been aware of the shadowing effect. The data's collected from other sources such as MoWIE field report shows that the PV orientation problem is common to all other places. Especially those systems installed at schools had a tilt angle as high as 40°. This has negative effect on the energy yield of the module. Figure 4.9 shows examples of varying PV orientation gathered from different regions of Ethiopia.

Figure 4.9 Examples of varying PV orientation

Regarding the system size installed in all the study area, the result shows that, two types of systems are installed 40Wp and 130Wpsystems. The 40Wp system is designed to power 1*7W LED, 3*2W dc LED light lamp, 1*15W hair cut machine or black & white TV, small tape or radio, and to charge mobile, but in all (5) households the system is serving only for lighting and mobile charging, even though the system has the capacity to power TV or radio because of low economic capacity the end users are forced to use the system only for lighting and mobile charging. The other system type observed during the field visit at the 15 house holds were the 130Wp AC/DC type system. This system has the capacity to power 2*7W LED, 3*2W, 3*1W dc LED light lamp, tape & radio, mobile charge, 12" or 14” TV (low power ac/dc TV mostly used in bus for long distance passengers), dc operate refrigerator (low power consumption normally called solar refrigerator)**.** Accordingly the actual device installed in the 15 households are 3*1w dc LED light lamp, mobile charge and 14” flat screen TV. Regarding the support structures, in all (20) SHS were traditional woods which are not even varnished and inspected by professional structural engineer. The setups of the local houses were random and irregular shape. This makes the installation very difficult especially the household systems. The support structures used were not strong and cannot withstand strong wind see Figure 4.10.


Photo taken by researcher 2016

Figure 4.10 Support structures used is not strong.

Other problems observed during the site visit in all the four kebeles, were there system components such as the cabinet and PV panel were unclean and covered by dust particles for a long time, end users are not well aware on the impact of soiling and dust impact on the output of the photovoltaic modules hence they fail to clean and most of the observed systems were covered by dust. PV modules are highly reliable, however, in polluted environments, over time; they will collect grime and dust. The photovoltaic cells already have low conversion efficiencies; the accumulation of sand and dust particles from the outdoor environment on their surface further reduces the generated output power. This is due to the reduction the solar radiation incident on the solar cell. This situation further exacerbate by poor sky clearance (see the difference in Figure 4.11).


Photo taken by Tewelde2016

Photo taken by Mona M. 2016

Comparison of sky clearanc and effect of dust on panel surface

Figure 4.11 Photovoltaic panel must be kept clean

As shown in Figure 4.11 unclear and polluted sky by dust particles can reduce the incoming radiation of the sunlight from reaching the solar cells and reduces solar system performance, so as to minimize this impact photovoltaic panel must be kept clean, moreover areas with low rain fall and desert prone to this problem. Therefore user’s awareness creation how dust particles can reduce the radiation of the sunlight and system performance should consider as a mandatory daily activity of end-users.

4.6. PV orientation analysis and evaluating the best orientation

To further support our findings regarding solar orientation and to evaluate the orientation, PVsyst software were used. Addis Abeba, Hawassa, Bahir-dar, Mekele and Adama areas PV system orientation were analyzed by the software. To conduct the analysis, first the location of the five areas (Table 4.4) used as an input to the software.

Table 4.4 Geographic location of 5 Main cities of Ethiopia

Location	**Latitude**	**Longitude**	**Elevation(m)**
Addis Ababa/Addis Abeba	9^0N	38.8^0E	2448
Hawassa	7.1^0N	38.3^0E	1983
Bahir-Dar	11.6^0N	39.5^0E	2070
Mekele	13.5^0N	39.5^0E	1911
Adama	8.6^0N	39.3^0E	1869

Secondly, the yearly average sun radiation in each months from NASA (Table4.5), collected. The result showed the radiation of the sun is at above 5.97kWh/m^2/day during the months from October to May, and the values are as lower as 5.41/4.75/4.87/5.54kWh/m^2/day respectively during the months from Jun to September (Table 4.5).

Table 4.5 NASA Surface meteorology and Solar Energy: RETScreen Data Ethiopia, Latitude 8, Longitude 38, Elivation2324 m

Month	***Air temperature***	***Relative humidity***	***Daily solar radiation - horizontal***	***Atmospheric pressure***	***Wind speed***	***Earth temperature***	***Heating degree-days***	***Cooling degree-days***
	°C	%	kWh/m^2/d	kPa	m/s	°C	°C-d	°C-d
January	18.0	42.0%	5.97	79.4	3.5	22.4	18	241
February	19.4	37.7%	6.38	79.3	3.2	24.4	3	257
March	20.5	41.9%	6.26	79.3	3.0	25.6	1	315
April	19.8	54.8%	6.12	79.2	3.1	24.1	5	288
May	18.6	65.5%	6.05	79.3	2.9	21.8	8	266
June	16.9	76.8%	**5.41**	79.4	3.0	18.6	29	213
July	15.8	79.5%	**4.75**	79.4	2.6	16.9	59	187
August	15.8	79.5%	**4.87**	79.4	2.3	16.8	54	192
September	16.1	76.1%	**5.54**	79.4	2.3	17.3	41	197
October	16.3	63.0%	6.17	79.4	2.8	17.8	49	197
November	16.9	48.4%	6.20	79.4	3.2	19.3	38	202
December	17.2	46.0%	6.02	79.4	3.4	20.5	33	215
Annual	**17.6**	**59.2%**	**5.81**	**79.4**	**2.9**	**20.5**	**338**	**2770**
Measured at (m)					10.0	0.0		

Document generated on Thu Apr 7 03:36:56 EDT 2016 from www.RETScreen.com

The data from NASA shows that the sun radiation is lower at the months of June–September (Table 4.5). The reason is that it is a rainy season, and the time of sun shine shorter than average. In Ethiopia, the angle between the sun shine and the vertical line when the sun is at the tropical Capricorn (south) is bigger than the angle when the sun is at the tropical cancer (north). If only considering the position of the sun, the sun radiation value on the land of Ethiopia at the date of December 21st (the tropical Capricorn) shall be less than the radiation value at the date of June 21st (the tropical cancer). On the contrary, the actual observing and surveying on the local residence, the raining season is in the months from June to September in Ethiopia. It exactly matches the data from NASA. From September to March is dry season, there is longer sunshine time during this season. Therefore this information obtained from NASA can help to compare with the result produced by the software, the actual observation and survey of the local residence. Accordingly irradiance result obtained in 5 cities (Addis Abeba, Adama, Mekele, Baher-dar and Hawassa) is analyzed with respect to NASA and local residence observation and presented below.

4.6.1. Orientation Result of Addis Ababa

The monthly orientation result with respect to irradiance for Addis Ababa, at Lat. 9^{0}N, Long 38.8^0 E and alt.2448m generated by the PVsyst software is presented below.

Table 4.6 PVsyst Orientation Result of Addis Ababa at 15^0

SN	ZONE	Calculations											
		Months	**Sun Radiation (KWh/m^2.day)**										
			Horizontal Plane	**Orientation of PV panel**									
				South-10^{0}Tilt	**15^0 from horizontal plane**								
					S	**S-W**	**W-**	**N-W**	**N-**	**N-E**	**E**	**S-E**	**% Loss**
1	Addis Ababa/ Finfinezuria	January	5.57	4.94	4.58	4.98	5.55	6.16	6.42	6.16	5.55	4.89	**13**
		February	5.57	5.17	4.93	5.13	5.54	5.9	6.06	5.9	5.54	5.13	**7.9**
		March	5.74	5.56	5.41	5.5	5.7	5.85	5.92	5.85	5.7	5.5	**1.4**
		April	5.35	5.41	5.39	5.36	5.32	5.23	5.18	5.25	5.34	5.38	**1.6**
		May	5.14	5.35	5.4	5.3	5.1	4.86	4.74	4.88	5.12	5.32	**0.5**
		June	4.68	4.93	5.01	4.89	4.65	4.38	4.25	4.39	4.67	4.9	**0.8**
		July	3.82	3.97	4.01	3.93	3.78	3.6	3.51	3.61	3.79	3.94	**0.5**
		August	3.8	3.87	3.88	3.84	3.77	3.67	3.61	3.68	3.78	3.85	**0.9**
		September	4.58	4.51	4.44	4.47	4.54	4.56	4.56	4.57	4.56	4.49	**0.2**
		October	5.56	5.25	5.04	5.2	5.54	5.82	5.95	5.82	5.54	5.2	**8.3**
		November	6.08	5.44	5.07	5.38	6.04	6.66	6.93	6.66	6.04	5.38	**12**
		December	5.68	4.97	4.57	4.92	5.66	6.35	6.66	6.35	5.66	4.92	**14.5**
		Y.Average	**5.13**	**4.97**	**4.81**	**4.9**	**5.09**	**5.25**	**5.31**	**5.26**	**5.1**	**4.91**	**3.3**

Table 4.6 shows, during summer and spring season (June, July, August and March, April, May) the irradiance is maximum at 15^0 tilt and 180^0 azimuth angles. During autumn and winter season the maximum irradiance is at 0^0 azimuths of the same tilt angle. This indicates that during summer and spring season the sun passes across the southern sky of Addis Ababa, and through the Northern sky of Addis Ababa during autumn and winter. Comparing the average yearly irradiance at 180^0 and 0^{0}azimuths of the same tilt angle (15^0) the maximum irradiance is obtained at 0^{0}azimuths which was 5.31kwh/m^2/day. This means the panel can collect maximum irradiance when it faces towards the north. MoWIE is recommended to all PV installers to install all the PV systems at 10^0 tilt and 180^0 azimuth angles. The yearly average irradiance at 10^0 tilt and180^0 azimuth is less than the yearly average irradiance at 15^0 tilt angle and 0^0 North by3.3%.

4.6.2. Orientation Result of Adama

The monthly meteo of Adama at Lat. 8.6^0N, Long.39.3^0 E alt. 1869m is depicted in the table below,

Table 4.7 PVsyst Orientation Result of Adama at 15^0

SN	ZONE	Calculations											
		Months	Sun Radiation (KWh/m^2.day)										
			Horizontal Plane	Orientation of PV panel									
				South-10^0 Tilt	15^0 from horizontal plane								
					S	S-W	W-	N-W	N-	N-E	E	S-E	% Loss
2	Adama	January	5.57	4.95	4.6	4.9	5.54	6.14	**6.4**	6.14	5.54	4.9	**12.8**
		February	5.57	5.18	4.94	5.13	5.53	5.89	**6.05**	5.89	5.53	5.13	**7.7**
		March	5.74	5.56	**5.42**	5.5	5.7	5.84	5.9	5.84	5.7	5.5	**-1.3**
		April	5.35	5.41	**5.39**	5.36	5.31	5.23	5.17	5.24	5.34	5.38	**-0.2**
		May	5.14	5.35	**5.41**	5.3	5.1	4.86	4.74	4.87	5.12	5.32	**0.6**
		June	4.68	4.93	**5.01**	4.88	4.64	4.37	4.24	4.39	4.66	4.9	**0.8**
		July	3.82	3.97	**4.01**	3.93	3.78	3.6	3.5	3.61	3.79	3.95	**0.5**
		August	3.8	3.88	**3.88**	3.84	3.77	3.66	3.61	3.67	3.78	3.85	**0**
		September	4.58	4.51	4.45	4.47	4.53	4.55	**4.55**	4.57	4.55	4.49	**0.4**
		October	5.56	5.25	5.05	5.2	5.53	5.81	**5.93**	5.81	5.53	5.2	**0.6**
		November	6.03	5.45	5.08	5.39	6.04	6.65	**6.91**	6.65	6.04	5.39	**11.8**
		December	5.68	4.98	4.58	4.93	5.65	6.34	**6.64**	6.34	5.65	4.93	**14.3**
		Yearly Ave	**5.13**	**4.95**	**4.82**	**4.9**	**5.09**	**5.24**	**5.3**	**5.25**	**5.1**	**4.91**	**3.4**

Table 4.7 shows, the irradiance vary as the azimuth angle varies from 0^0 azimuths (North) to south azimuth (180^0) in both directions (east and west).During the months from September to February the optimal irradiance is obtained at the north azimuth, this shows that during these six months the sun is passing along the Northern direction of Adama and the PV panel can collect maximum irradiance if it is installed at 15^0 tilt angle towards the north. From March to August the maximum irradiance is obtained at 15^0 tilt angles and 180^0 azimuth angle, this tells us the sun is passing along the southern sky of Adama land and the PV panel can collect maximum irradiance if it is installed at 15^0 tilt angles towards the south.

4.6.3. Orientation Result of Mekele

Mekele is the capital city in the northern Ethiopia of Tigrai region. It is located around 780 kilometers north of the Ethiopian capital Addis Ababa. The monthly meteo of Mekele at Lat. 13.5^0N, Long.39.5^0E and Alt. 1911m is,

Table 4.8 PVsyst Orientation Result of Mekele at 15^0

SN	ZONE	Calculations											
		Months	Sun Radiation (KWh/m^2.day)										
			Horizontal Plane	Orientation of PV panel									
				South-10^0Tilt	15^0 from horizontal plane								
					S	S-W	W-	N-W	N-	N-E	E	S-E	% Loss
3	Mekele	January	3.08	2.68	2.46	2.65	3.07	3.47	**3.64**	3.47	3.07	2.65	**15.3**
		February	4.03	3.67	3.45	3.63	4.02	4.37	**4.52**	4.37	4.02	3.63	**10.37**
		March	4.99	4.76	**4.6**	4.71	4.96	5.17	5.25	5.17	4.96	4.71	**-0.5**
		April	6.12	6.11	**6.05**	6.04	6.06	6.04	6.02	6.06	6.09	6.06	**-0.4**
		May	7.15	7.39	**7.47**	7.31	7.08	6.8	6.65	6.82	7.11	7.34	**-0.3**
		June	7.28	7.63	**7.73**	7.56	7.2	6.8	6.61	6.82	7.23	7.58	**0.6**
		July	6.55	6.81	**6.88**	6.75	6.49	6.19	6.03	6.21	6.52	6.77	**0.5**
		August	5.97	6.05	**6.03**	5.99	5.91	5.8	5.73	5.81	5.94	6.01	**-0.1**
		September	5.42	5.28	5.17	5.23	5.38	5.5	**5.54**	5.51	5.41	5.25	**2.4**
		October	4.55	4.21	4.01	4.17	4.53	4.84	**4.98**	4.84	4.53	4.17	**8.4**
		November	3.66	3.2	2.94	3.17	3.64	4.08	**4.28**	4.08	3.64	3.17	**14**
		December	3.02	2.57	2.33	2.55	3.01	3.46	**3.65**	3.46	3.01	2.55	**17.4**
		Y.Average	5.15	5.03	4.93	4.99	5.12	5.21	5.24	5.22	5.13	5	**2**

According to the result in table 4.8 for mekele at 15^0 tilt angle from the horizontal plane, autumn and winter has a maximum irradiance at an azimuth angle of zero degree.

During summer and spring season, the irradiance is maximum at south azimuth. So, in Mekele during autumn and winter the sun passes across the North. During summer and spring season the sun crosses to the sky of mekele land across the south direction. But, if we compare the yearly average irradiance in each azimuth the system can perform better if it is installed at 15^0 tilt angle and 0^0 azimuth angle.

4.6.4. Orientation Result of Bahir Dar

Bahir Dar is the third largest city in Ethiopia, after Addis-Ababa and Dir-Dawa. It is the capital of the Amhara region, inhabited by the Amhara people; the countries ethnically and geographically second largest group. The monthly meteo of Bahir-Dar at Lat.11.6^{0}N, Long.39.5^{0}E and alt.2070m is.

Table 4.9 PVsyst Orientation Result of Bahir-Dar at 16^0

SN	ZONE	Calculations											
		Months	Sun Radiation (KWh/m^2.day)										
			Horizontal Plane	Orientation of PV panel									
				South-10^{0}Tilt	16^0 from horizontal plane								
					S	S-W	W-	N-W	N-	N-E	E	S-E	% Loss
4	Bahirdar	January	5.57	4.89	4.51	4.83	5.53	6.19	6.48	6.19	5.53	4.83	**14**
		February	5.57	5.13	4.87	5.08	5.53	5.84	6.12	5.94	5.53	5.08	**8.8**
		March	5.74	5.52	5.97	5.46	5.7	5.89	5.36	5.89	5.7	5.46	**4**
		April	5.35	5.37	5.34	5.32	5.31	5.27	5.23	5.28	5.34	5.34	**-0.3**
		May	5.14	5.32	5.36	5.28	5.1	4.89	4.79	4.91	5.12	5.29	**-0.3**
		June	4.68	4.9	4.97	4.87	4.65	4.41	4.28	4.42	4.67	4.88	**-0.2**
		July	3.82	3.95	3.98	3.92	3.78	3.62	3.53	3.63	3.79	3.93	**0.4**
		August	3.8	3.85	3.85	3.82	3.76	3.69	3.64	3.7	3.78	3.83	**0**
		September	4.58	4.49	4.41	4.45	4.53	4.58	4.59	4.6	4.55	4.46	**-0.9**
		October	5.56	5.21	4.98	5.16	5.53	5.86	6	5.86	5.53	5.16	**7**
		November	6.08	5.38	4.99	5.33	6.05	6.72	7.01	6.72	6.05	5.33	**13.2**
		December	5.68	4.91	4.49	4.85	5.64	6.4	6.73	6.4	5.64	4.85	**15.6**
		Y.A	**5.13**	**5.13**	**4.76**	**4.86**	**5.09**	**5.28**	**5.36**	**5.29**	**5.1**	**4.87**	2.2

According to the result shown in table 4.9, both seasons' autumn and winter have maximum irradiance at the same azimuth angle of 0^0. But, the irradiance values in each month are different. During spring and summer seasons in Bahir-dar, the maximum irradiance is 5.97/5.34/5.36 and 4.97/3.98/3.85 kwh/m^2/day at south azimuth (180^0). But the best (5.36kwh/m^2/day) yearly average irradiance is obtained at zero degree azimuth angle. Accordingly the PV panel can perform optimally, if it is installed towards the north at 16^0 tilt angle permanently.

4.6.5. Orientation Result of Hawassa

Awasa (also spelled Awassa or Hawassa) is a city in Southern Ethiopia, on the shores of Lake Awasa in the Great Rift Valley. It is located 270 km south of Addis Ababa via Debre Zeyit, 130 km east of Sodo, and 75 km north of Dilla. The town serves as the capital of the South Nations, Nationalities, and People's Region, and is a special zone of this region. The monthly meteo of Hawassa at Lat. 7.1^{0}N, Long.38.5^{0}E alt. 1983m is,

Table 4.10 PVsyst Orientation Result of Hawassa at 15^0

SN	**ZONE**	**Calculations**											
		Months	**Sun Radiation (KWh/m^2.day)**										
			Horizontal Plane	**Orientation of PV panel**									
				South-10^{0}Tilt	**15^0 from horizontal plane**								
					S	**S-W**	**W-**	**N-W**	**N-**	**N-E**	**E**	**S-E**	**% Loss**
5	HAWASA	January	3.08	2.75	2.57	2.73	3.07	3.39	**3.53**	3.39	3.07	2.73	**12.4**
		February	4.03	3.75	3.57	3.72	4.01	4.28	**4.4**	4.28	4.01	3.72	**8**
		March	4.99	4.85	**4. 8**	4.73	4.96	5.08	5.13	5.08	4.96	4.8	**-0.5**
		April	6.12	6.21	**8.15**	6.2	6.06	5.94	5.87	5.95	8.09	6.I 7	**13.5**
		May	7.15	7.5	**7.61**	7.43	7.07	6.67	6.48	6.69	7.1	7.46	**-0.4**
		June	7.28	7.74	**7.9**	7.67	7.19	6.68	6.43	6.7	7.22	7.7	**1**
		July	6.55	6.9	**7.02**	6.84	6.48	6.08	5.88	6.1	6.51	6.87	**0.9**
		August	5.97	6.14	**6.17**	6.09	5.92	5.71	5.6	5.73	5.95	6.11	**0.2**
		September	5.42	5.37	5.3	5.32	5.38	5.4	**5.41**	5.42	5.41	5.34	**0.4**
		October	4.55	4.3	4.14	4.26	4.52	4.75	**4.85**	4.75	4.52	4.26	**6**
		November	3.66	3.28	3.07	3.25	3.64	4	**4.15**	4	3.64	3.25	**11.1**
		December	3.02	2.65	2.44	2.63	3.01	3.38	**3.54**	3.38	3.01	2.63	**14.4**
		Y.A	**5.15**	**5.13**	**5.07**	**5.08**	**5.12**	**5.12**	**5.14**	**5.13**	**5.13**	**5.09**	**0.1**

According Table 4.10, during winter and autumn the maximum irradiance is 5.41/4.85/4.15 kwh/m^2/day and 3.54/3.53/4.4kwh/m^2/day at the same 0^{0}azimuth angle (north) for the consecutive six months. This shows that, from September to February the sun passes across the northern sky of Hawassa land, therefore the PV panel can perform optimal if it is installed at 15^0 tilt and 180^0 azimuth angle.

During spring and summer seasons the maximum irradiance is at 180^0 azimuth angle i.e. 4.8/8.15/7.61 and 7.9/7.02/6.17kwh/m^2/day. This shows that the sun position is certainly shifted from north sky during the autumn and winter to the South direction that's why the irradiance intensity becomes higher at this location.

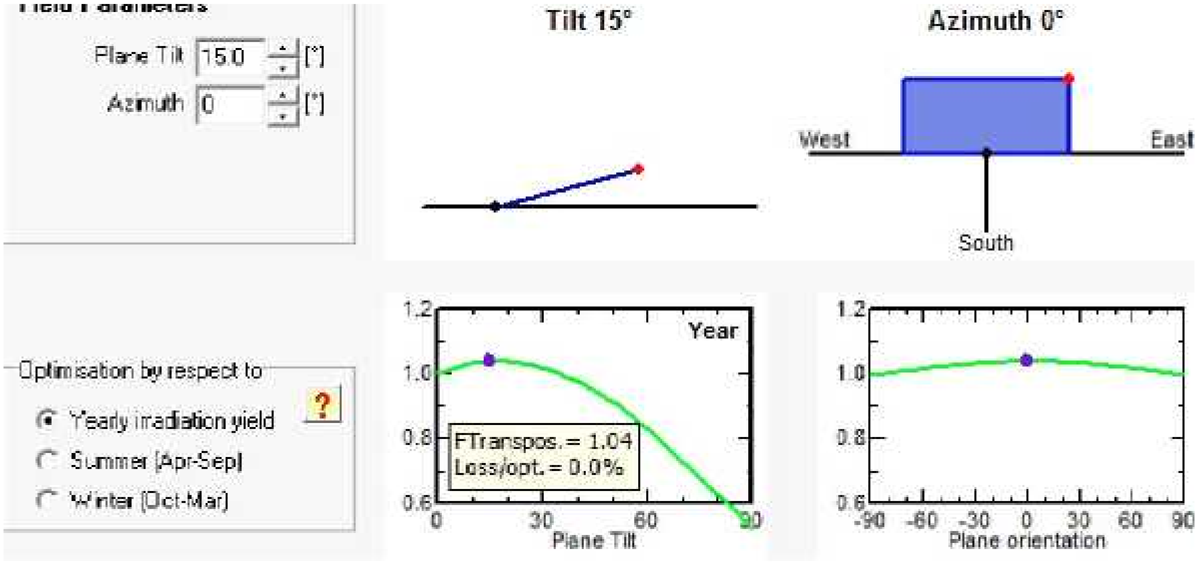
The maximum yearly average irradiance is 5.11kwh/m^2/day which is at the northern azimuth angle and the PV panel can collect a maximum irradiance if it is installed at 15^0 tilt angle and 0^0 azimuth angle.

4.6.6. PVsyst Orientation Simulation Result

The PVsyst software is used in order to simulate optimal orientation. The behavior of the solar PV system simulation depends on the tilt angle of the PV system, azimuth angle and site meteorological conditions such as solar radiation.

The meteorological site selected for this analysis are, Addis Ababa, Adama, Mekele, Hawassa and Bahir-Dar in Ethiopia, because majority of the solar PV systems are installed in those regions. The results obtained are presented below.

4.6.7. Optimization result of Addis Ababa/Finfinezuria



Plane Tilt 15.0 [°]
Azimuth 0 [°]

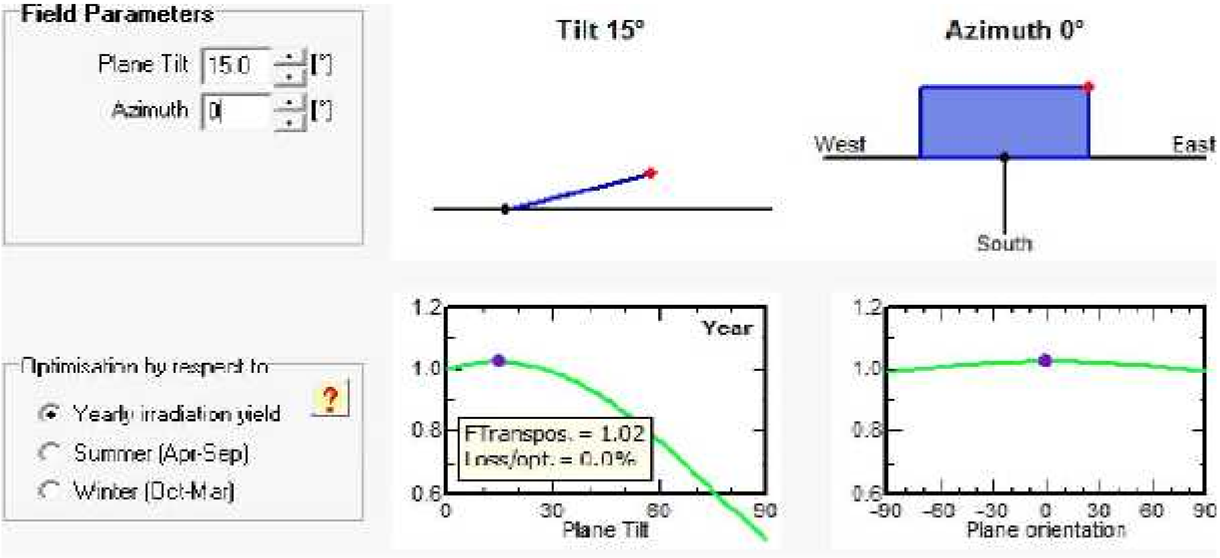
Optimisation by respect to
● Yearly irradiation yield
○ Summer (Apr-Sep)
○ Winter (Oct-Mar)

FTranspos. = 1.04
Loss/opt. = 0.0%

Figure 4.12 Optimization result of Addis Ababa/Finfine-zuria

The simulation result for Addis Ababa/Finfine zuria shows, the system can receive its optimal yearly irradiance(Loss/opt. =0%), if and only if the system fixes at 15^0 tilt angle and 0^0azimuth PV panel orientation, according to Table 4.6result, the system can receive 5.31kwh/m^2/day averagely in each day of the year and the total yearly irradiance on its collector plane is 1911.6kwh/m^2/year, this amount of energy can convert in to usable form of power (the derivative of energy)depending on the conversion efficiency of the PV module and other system component efficiency.

4.6.8. Optimization result of Adama


Field Parameters

Plane Tilt 15.0 [°]

Azimuth 0 [°]

Optimisation by respect to

● Yearly irradiation yield

○ Summer (Apr-Sep)

○ Winter (Oct-Mar)

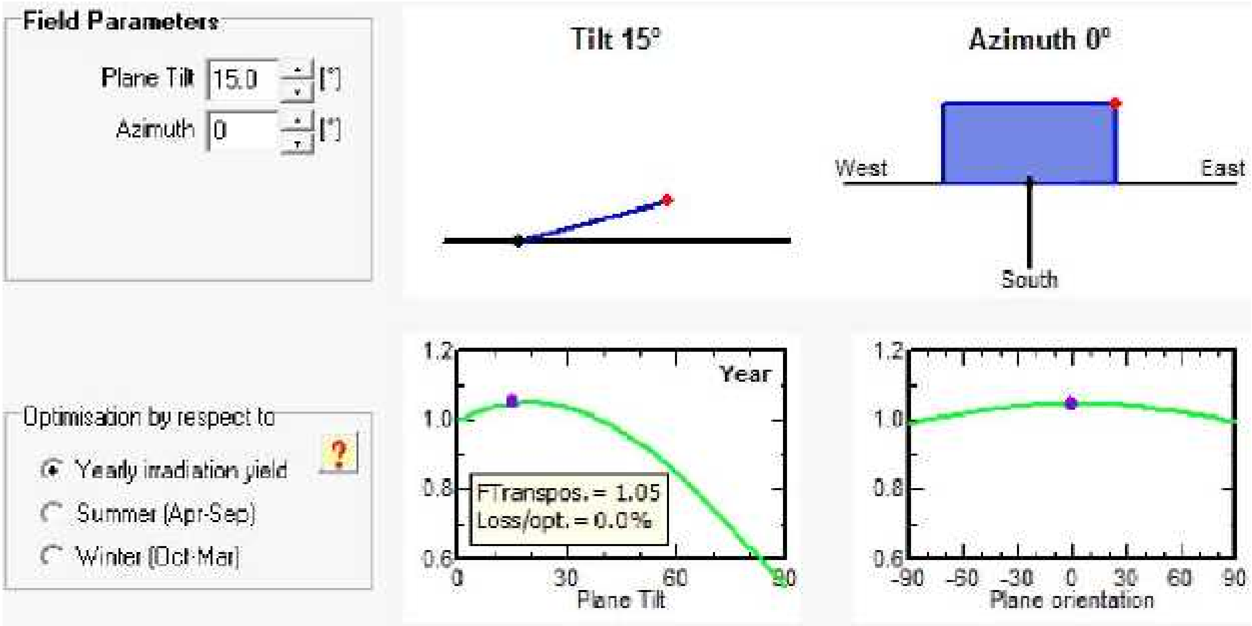
FTranspos. = 1.02

Loss/opt. = 0.0%

Figure 4.13 Optimization result of Adama

According to the software result above the optimum yearly irradiance yield on the collector plane at Adama is at an azimuth angle of 0^0 and tilt angle of 15^0, if the system is installed keeping this standard the amount of radiation loss per optimum receiving capacity of the PV module is zero. Taking the result in Table 4.7, the daily average yearly irradiance of Adama at this orientation standard is 5.3kwh/m2/day, accordingly the system can collect 1908kwh/m^2/year annually, and this amount of energy can convert in to usable form of power depending on the conversion efficiency of all the system component efficiency.

4.6.9. Optimization result of Mekele



Field Parameters

Plane Tilt 15.0 [°]

Azimuth 0 [°]

Optimisation by respect to

● Yearly irradiation yield

○ Summer (Apr-Sep)

○ Winter (Oct-Mar)

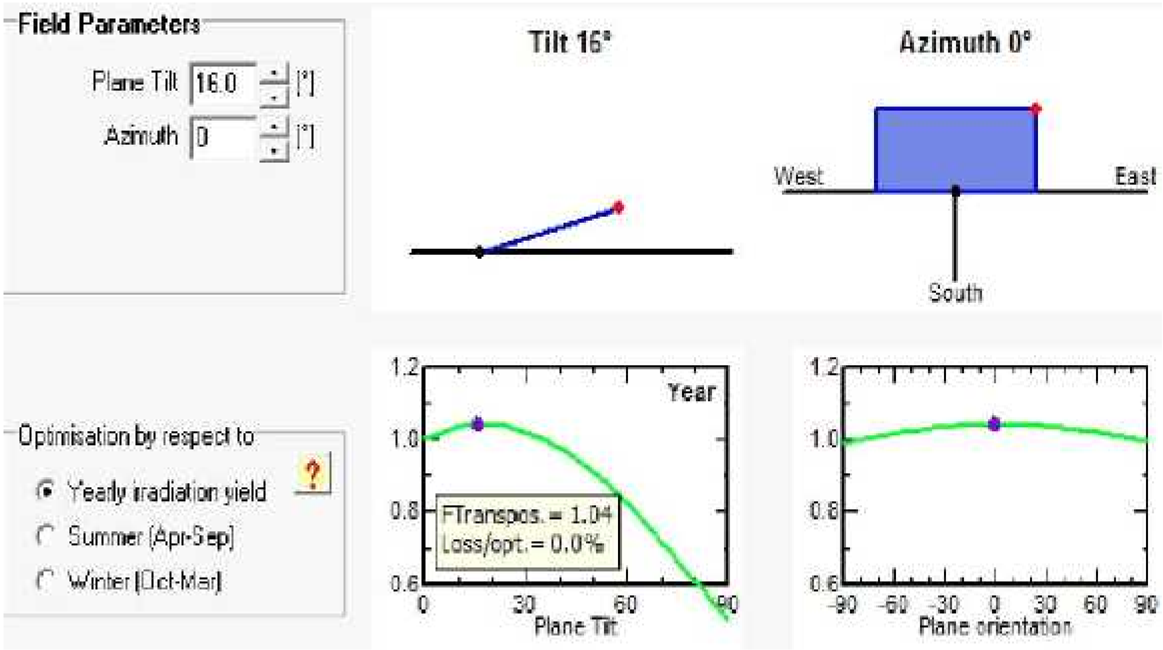
FTranspos. = 1.05

Loss/opt. = 0.0%

Figure 4.14 Optimization result of Mekele

As shown in the result Figure 4.14 the loss per optimal irradiance on the PV system for Mekele is zero at PV panel tilt angle of 15^0 and azimuth angle of zero degree. Table 4.8 describes that, the yearly average of daily irradiance of Mekele at this orientation is 5.24kwh/m^2/day, this shows that the PV panel can collect 1886.4kwh/m^2/year and converts in to usable form of power depending on the conversion efficiency of the entire system component.

4.6.10. Optimization result of Bahir-Dar


Field Parameters

Plane Tilt 16.0 [°]

Azimuth 0 [°]

Optimisation by respect to

● Yearly irradiation yield

○ Summer (Apr-Sep)

○ Winter (Oct-Mar)

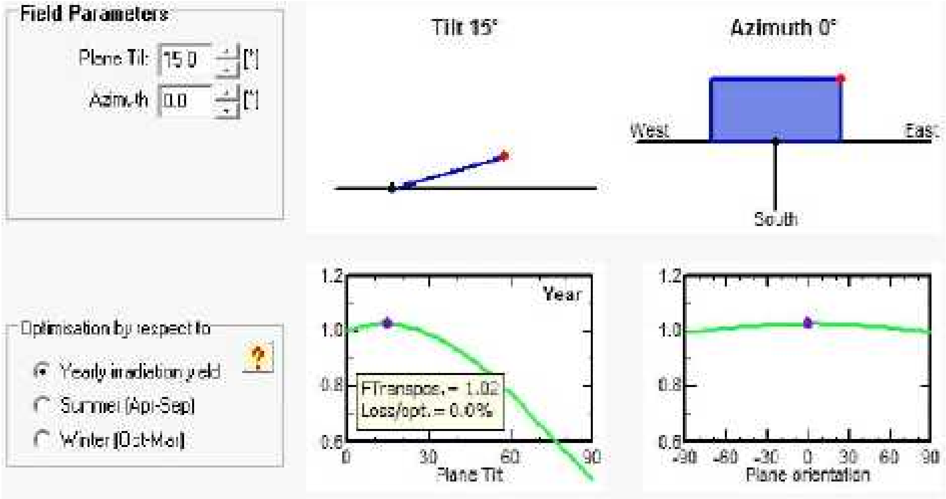
FTranspos. = 1.04

Loss/opt. = 0.0%

Figure 4.15 Optimization result of Bahir-Dar

The optimization result of Bahir-Dar shown in the simulation result figure 4.15 describes, the yearly irradiance loss per optimal yield on collector plane at Bahir-Dar is 0kwh/m^2/year, which is when the PV system is tilted at 16^0 and 0^0 azimuth angle, Table 4.9 shows that, at this system orientation the PV system can collect an average of 5.36kwh/m^2 every day implies that 1929.6kwh/m^2/year. This amount of energy can also convert in to usable form of electricity depending on the property nature of conversion efficiency.

4.6.11. Optimization result of Hawassa



Plane Tilt 15.0 [°]
Azimuth 0.0 [°]

Optimisation by respect to
● Yearly irradiation yield
○ Summer (Apr-Sep)
○ Winter (Oct-Mar)

FTranspos. = 1.02
Loss/opt. = 0.0%

Figure 4.16 Optimization result of Hawassa

According to PVSyst software simulation optimization result for Hawassa, the yearly irradiance yield collected the collector plane at 15^0 tilt and 0^0 azimuth angle is 1850.4kwh/m^{2}year, taking5.14kwh/m^2/day (Table 4.10). The loss per optimal irradiance on the PV panel is zero. Based on this analysis the 1850.4kwh/m^{2}year harvested by the PV panel can convert in to usable form of light depending on the system components conversion efficiency.

CHAPTER-FIVE

5. Conclusion and Recommendation

5.1. Conclusions

This thesis examines the state of solar PV dissemination in Ethiopia. Most of the rural setting (98%) still lack electricity. The solar distribution, which is done by MoWIE, is not sufficient to deliver the required service. However, the distributed solar home systems improved the social economic activities of the off grid people and quality of life. In addition to inadequacy of the distribution amount, there are other problems for successful dissemination. These are:- (I)the project-based approach for distribution involves single, large-scale tender based procurements as opposed to a continuous supply of solar lighting products; (ii) in ability to persuade local banks to lend for solar PV products as a result sufficient capital and financing were not available for local private companies to respond to the large tenders (with result to their limited involvement); (iii)no established market link between the importers (located mainly in Addis Ababa) and distributors/installers located in rural areas as a result customers face problem of maintenance and availability of spare parts; (iv)limited efforts to promote the benefits of solar PV systems and (v) absence of local component producers, which made system cost very high. (vi)absence of regulatory and legal framework based on national standards, rural public awareness campaign. Consequently, small amount of solar PV systems are distributed throughout the country thereby most of the rural households still living without access to electricity which expose them to depend on fuel based lighting including fossil and solid biomass fuels. This will contribute to green house gas emission, in and out door air pollution and local environmental degradation**.**

Other problems that were observed during this study relate to absence of national standards for PV orientation installation. The study shows that, installation orientation does not follow certain guide lines as evidenced from observed variety of tilt angle. The system orientation, the software analysis indicates that the system performance will be optimized if the orientation is put in place provide that, the tilt angle is 15^0 in all parts of the country except Bahir-Dar and around Bahir-Dar which is 16^0 tilt angle and its azimuth angle is 0^0(towards the north). However the majority of (100%) the solar systems during the study were fall within 0^0-5^0 tilt angle this shows the systems are not giving the required service, if this situation continue the households probably distrust the system if they did not get the required amount of energy. As a result, the following recommendation is provided based on the findings.

5.2. Recommendations

Based on the findings from the study the following recommendations are provided

- ✓ Provision of solar systems with a continuous supply rather than project based supply in order to ensure its sustainability.
- ✓ Introducing national regulatory and legislative framework for solar PV technology for the rural sector and incentives to specifically promote and encourage the rural populations.
- ✓ Popularizing the technology to rural populations to create possibilities for gaining access to energy.
- ✓ A financial support mechanism (e.g. performance grants, revolving fund, investment fund, micro-credit scheme, carbon finance, etc.) that would help to subsidize the cost of these appliances or provide households with access to credit is needed to enable them to make purchases that would normally simply not be affordable.
- ✓ Strengthening enterprises involved in supplying solar PV technologies to rural communities in Ethiopia.
- ✓ Provision of training on maintenance to local end-users. This will be a sustainable solution where the technicians are available in the nearby of system to be distributed.
- ✓ The panel orientation also should be at 15^0tilt north to get the optimum irradiance at all location of Ethiopia except Bahir-Dar and around Bahir-Dar which is 16^0 tilt angle to the north for any system type.
- ✓ Further study on the carbon saving and sequestration by solar PV electrification can be a source of income by carbon trading and will make such kind of projects more sustainable.
- ✓ Conduct demographic study in the area which can help to know the real financial capacity of the off-grid community to obtain PV technologies, which will help to determine the type.

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Annex

Table –AsystemDesign and Descriptions of the 28,324 SHS

No	System size	Users Demand	Designed Daily Energy [wh/day]
1	8Wp	1*1w, 1*2w LED light lamp + hand radio + mobile Charge	**20**
2	10Wp	2*1w, 2*2w LED light lamp + hand radio + mobile Charge	**30**
3	20Wp	1*5W LED, 3*2W dc LED light lamp + small radio + mobile Charge	**60**
4	40Wp	1*7W LED, 3*2W dc LED light lamp + 1*15W hair cut machine or Black & White TV + small Tape & Radio + mobile Charge	**160**
5	60Wp	1*7W LED, 3*2W dc LED light lamp + Tape & Radio + mobile Charge + 12" or 14" TV (low power ac/dc TV mostly used in Bus for long distance passengers)	**200**
6	75Wp	2*7W LED, 2*2w dc LED light lamp + Tape & Radio + 12" or 14" TV (low power ac/dc TV mostly used in Bus for long distance passengers)	**250**
7	80Wp	2*7W LED, 4*2w dc LED light lamp + Tape & Radio + mobile Charge + 12" or 14" TV (low power ac/dc TV mostly used in Bus for long distance passengers)	**270**
8	100Wp	2*7W LED, 6*2w dc LED light lamp + Tape & Radio + mobile Charge + 12" or 14" TV (low power ac/dc TV mostly used in Bus for long distance passengers)	**320**
9	130Wp	2*7W LED, 3*2w, 3*1w dc LED light lamp, + Tape & Radio + mobile Charge + 12" or 14" TV (low power ac/dc TV mostly used in Bus for long distance passengers) + dc operate refrigerator (low power consumption normally called solar refrigerator)	**420**

Table – B System Type and Specification of the nine systemsofSHS

No	Description		System Type 1	System Type 2	System Type 3	System Type 4	System Type 5	System Type 6	System Type 7	System Type 8	System Type 9
1	Crystalline modulewith complete module mount structure and tilt adjustment	Capacity	8wp	10Wp	20Wp	40Wp	60Wp	75Wp	80Wp	100Wp	130Wp
		Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity	1	1	1	1	1	1	1	1	1
2	Battery gel, with well ventilated box	Capacity	20Ah	24Ah	40Ah	80Ah	100Ah	120Ah	130Ah	170Ah	220Ah
		Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity	1	1	1	1	1	1	1	1	1
3	Charge controller, 12Vdc	Capacity	2A	2A	3A	5A	6.6A	6.6A	8A	10A	12A
		Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity	1	1	1	1	1	1	1	1	1
4	Pure sine wave Inverter	Capacity	NA	NA	NA	NA	150Watt	200Watt	200Watt	250Watt	300Watt
		Unit					Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity					1	1	1	1	1
5	dc LED lamp with holder and on-off switch	Size	NA	NA	5Watt	7Watt	7Watt	7Watt	7Watt	7Watt	7Watt
		Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity			1	1	1	2	2	2	2
6	dc LED lamp with holder and on-off switch	Size	1watt	1watt	NA	NA	NA	NA	NA	NA	1watt
		Unit	Pcs	Pcs							Pcs
		Quantity	1	2							3

7	dc LED lamp with holder and on-off switch	Size	2watt	2watt	2watt	2watt	2watt	2watt	2watt	2watt	2watt
		Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity	1	2	3	3	3	2	4	6	3
8	Circuit Breaker	Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
8.1	Size: 2A 12V dc	Quantity	2	2	2						
8.2	Size: 3A 12V dc	Quantity				2	1	1	1	1	1
8.3	Size: 5A 12V dc	Quantity					1				
8.4	Size: 8A 12V dc	Quantity									
8.5	Size: 10A 12V dc	Quantity						1	1	1	
8.6	Size: 16A 12V dc	Quantity									1
8.7	Size: 1A 230V ac	Quantity					1	1	1	1	1
9	dc to dc voltage Converter from 12v dc into option to use 3, 4.5, 6, 7.5 and 9 V dc	Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity	1	1	1	1	1	1	1	1	1
10	dcmobile charging socket with different pin plug (for different mobile model)	Unit	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity	1	1	1	1	1	1	1	1	1
11	AC socket outlet	Unit					Pcs	Pcs	Pcs	Pcs	Pcs
		Quantity					1	1	1	1	2
12	Cablefor interconnection and installation	Size	2*1.5mm^2	2*1.5mm^2	2*1.5mm^2	2*2.5mm^2	2*2.5mm^2	2*2.5mm^2	2*2.5mm^2	2*2.5mm^2	2*2.5mm^2
		Unit	meter	meter	meter	meter	meter	meter	meter	meter	meter
		Quantity	25	40	40	40	40	40	60	75	75

Table –C, List of Solar Micro Enterprise Technicians at installation time

	Name of Micro Technicians Enterprise	**Region**	**Zone**
1	Adama Tech. team micro enterprise	Oromiya	**East shoa**
2	Sebeta Tech. Team micro enterprise	Oromiya	**FinfineZuria**
3	Ambo Tech. team micro enterprise	Oromiya	**West Shoa**
4	Welliso Tech. team micro enterprise	Oromiya	**South west shoa**
5	Nekemte Tech. team micro enterprise	Oromiya	**East Wellega**
6	Shambo-Fincha Tech. team micro enterprise	Oromia	**HoroWellega**
7	Gimbhi Tech. team micro enterprise	Oromia	**West Wellega**
8	Jima Tech. team micro enterprise	Oromia	**Jimma**
9	Metu Tech. team micro enterprise	Oromia	**Illubabor**
10	Debrebirhan Tech. team micro enterprise	Amahara	**North Shoa**
11	Desie Tech. team micro enterprise	Amahara	**South Wello**
12	Woldiya Tech. team micro enterprise	Amahara	**North Wello**
13	Fiche Tech. team micro enterprise	Oromia	**North Shoa**
14	Gayint Tech. team micro enterprise	Amahara	**South Gonder**
15	Gonder Tech. team micro enterprise	Amahara	**North Gonder**
16	Mekele Tech. team micro enterprise	Tigray	**Central**

17	Humera Tech. team micro enterprise	Tigray	**West Tigray**
18	DebreMarkos Tech. team micro enterprise	Amahara	**East Gojjam**
19	Dangilla Tech. team micro enterprise	Amahara	**Awi**
20	Bahir Dar Tech. team micro enterprise	Amahara	**West Gojjam**
21	Metekel Tech. team micro enterprise	BeneshangulGumuz	**Metekel**
22	Wolkite Tech. team micro enterprise	SNNP	**Guraghe**
23	Hosaena Tech. team micro enterprise	SNNP	**Hadiya**
24	Asela Tech. team micro enterprise	Oromia	**Arusi**
25	Shashemene Tech. team micro enterprise	Oromia	**West Arusi**
26	Goba-Robe Tech. team micro enterprise	Oromia	**Bale**
27	Hageremariam Tech. team micro enterprise	Oromia	**Gujji**
28	Harer Tech. team micro enterprise	Oromia	**West Harerghe**
29	Yemm Micro Technicians Enterprise	SNNP	**Yemm**
30	Bench Maji Micro Technicians Enterprise	SNNP	**Bench Maji**
31	KanbataTembaro Micro Technicians Enterprise	SNNP	**KanbataTenbaro**
32	Cheha Micro Technicians Enterprise	SNNP	**Guraghe, Cheha**
33	Mareko Micro Technicians Enterprise	SNNP	**Guraghe, Mareko**
34	Qebena Micro Technicians Enterprise	SNNP	**Guraghe, Qebena**
35	Enemore Micro Technicians Enterprise	SNNP	**Guraghe, Enemore**
36	Muher Micro Technicians Enterprise	SNNP	**Guraghe, Muher**
37	Diredawa Tech. team micro enterprise	Diredawa	**Diredawa**
38	**Jijjiga Tech. team micro enterprise**	**Somali**	**Jijjiga**

Focus Group Discussion Guideline

Instruction to Discussion Moderator

- The target group for this discussion are men and women older than 7 years of age
- The group should consist of more than 6end users
- Hire a translator for the duration of the discussion if required (Sidama Zone Energy office Expert and Dilagumbe cooperative chair man)
- Follow these guidelines for the discussion
- Introduce yourself and the project
- Explain the purpose of the discussion
- Make discussants feel free to express their thoughts fully (stress voluntary participation and confidentiality, all opinions are equally appreciated)

Introduction by Moderator

- Welcome, thank you for coming. I am Dr Solomon Abebe, AbadiTesfay. We work for Addis Ababa, University Institute Technology.The University in partnership with the Regional Bureau of Water and Energy and your Wereda office is working to enhancethe social and technical benefit of solar energy projects in your area to address your needs through research.
- We want you to help us understand what energy sources you use for lighting, how you get them, and if you are aware of solar lighting. Your answers will help us develop the research to better suit you.
- We want to stress that this discussion is entirely voluntary and we shall ensure your answers are kept confidential. The discussion will take ½ an hour. If you have questions please forward them.
- Now, if the group wishes to continue let us start by introducing ourselves – please state your name, age, education, whether you are married.

Table –D በግሩፕውይይትወቅትየኢነርጂአቅርቦትናአጠቃቀምመረጃመሰብሰቢያቅፅ

1	ቴክኖሎጂትውውቅ						
2	ስለሶላርመብራትቴክኖሎጂሰምተውያውቃሉ?	(አዎ=1, የለም=0)					
3	(ለመረጃሰብሳቢ - ስለሶላርመብራትግለጽ)						
4	ስለሶላርመብራትከሰሙከየትሰሙ?						
	1=ከሬዲዮ						
	2=ከቴሌቪዥን						
	3=ከጋዜጣ						
	4=ከልማትሠራተኞች						
	5=ከጎረቤትናዘመድ						
	6=ሌላ						
	ይገለጽ						
5	የሶላርመብራትአይተውያውቃሉ?	(አዎ=1, የለም=0)					
6	የሶላርመብራትቴክኖሎጂተጠቃሚመሆንይፈልጋሉ?	(አዎ=1, የለም=0)					
7	የሶላርመብራትተጠቃሚመሆንየሚፈለጉከሆነፍላጎትዎከም ንየመነጨነው?						
	የመብራትወጪንስለሚቀንስ	(አዎ=1, የለም=0)					
	ጭስስለሚቀንስ	(አዎ=1, የለም=0)					
	ሌሎችምክንያቶች	(አዎ=1, የለም=0)					
	ይገለጽ						

8	ስለቤተሰቡየመረጃምንጭ						
9	ጠቃሚመረጃዎችንበዋነኛነትከየትያገኛሉ?	ከሬዲዮ	1				
		ከቴሌቪዥን	2				
		ከጋዜጣ	3				
		ከልማትሠራተኞች	4				
		ከጎረቤትናዘመድ	5				
		ሌላ	6				
		ይገለጽ					

Table - E. Reporting Temple and Background of FGD participants

Institute	**Addis Ababa University Institute Technology/Energy center**
Advisor	Solomon Abebe(Ph.D)
Research Title	Optimizing the Technical and Social Benefits of solar photovoltaic Technologies in Ethiopia.
Selected Site	➢ SNNP Region , Sidama Zone, ShebedinoWereda,DelagumbeKebele ➢ Amhara Region, North Shoa zone, Minjarwereda, Adamakebele ➢ Oromia Region, East shoa zone, Adamawereda, Mekuyeharokebele and ➢ Tigrairegion north west zone, Asgedetsimblawereda, Adimehamedaykebele
Date of FGD	April 20 - May 30, 2016
Field Researcher	AbadiTesfay

No.	**Queries**	**Notes**						
1	Location and date Dilagumbe Date: 20/04/2016 GC	Region, Zone: SNNP/Sidama Wereda: Shebedino Kebele: Dilagumbe Cooperative name: Aresho						
2	Group list	Name of participant	Phone no.	Sex	Age	Education	Marital staus	
		AleneAmalo	09-11-72- 01-88	M	42	8th	Married(Cooperative chair man)	
		YosefYokamo	09-16-77-8202	M	35	5th	Married	
		GechamoReja	09-61-61-33-82	M	60	6th	Married	
		MilkiasYonte	---------	M	39	Basic	Married	
		MabratuMengestu	---------	M	36	Basic	Married	

		Elias Melke	--------	M	37	Basic	Married	
		Haile Eyasu	-------	M	36	Basic	Married	
		HadaHalisu	--------	M	33	Basic	Married	
		MatewosBushra	-------	M	40	Basic	Married	
		AdaneAmelo	-------	M	39	Basic	Married	
		SukurtaAmelo	-------	M	37	Basic	Married	

No.	Queries	Notes						
1	Location and date MinjarShenkora Date: 01/05/2016 GC	Region, Zone: Amhara, NortheShoa Wereda: Minjarshenkora Kebele: Adama Cooperative name: AdamaBirhan						
2	Group list	Name of participants	Phone no.	Sex	Age	Education	Marital status	
		WeldetsadkBanjaw	0923826512	M	75	Qesis	Married	
		BegashawWeldetsadk	---------	M	32	Illiterate	Married	
		BogaleAshni	------------	M	40	Illiterate	Married	
		LenchaKasaye	------------	M	41	Basic	Married	
		KetemaGoshme	------------	M	40	Basic	Married	
		BegashawTilahun	------------	M	42	Illiterate	Married	

No.	Queries	Notes						
1	Location and date Adama Date: 10/05/2016 GC	Region, Zone: Oromia, East shoa Wereda: Adama Kebele: Mekuyeharo Cooperative name: Mekuyeharo						
2	Group list	Name of participant	Phone no.	Sex	Age	Education	Marital status	
		GetahunWeldetsadik	0912236531	M	50	Basic	Married	

		Mri/ AbebaweGetahun	0910424921	M	35	Church education(Kidase)	Married	
		MestewatDumase	0922362430	M	40	Basic	„	
		TegeneGetahun	---------	M	36	6th	„	
		SeyfuEshetu	--------	M	36	4th	„	
		EsheteBaye	--------	M	40	5th	„	
		AbzaweKebede	--------	M	39	2nd	„	
		GulemaAbebe	--------	M	36	4th	„	
		EhtaferahuWeldetsadk	-------	F	40	Basic	„	
		KebedeWeldetsadk	-------	M	43	Basic	„	
		AlemeLule	-------	M	60	Basic	„	
3	Focus Group Discussionattitude towards PV SHS based electrification							
	Thank participants							
	Take group picture							

1. Observation Checklist for PV systems

	Visual inspection of Pv array	
S.No.	**Main Check Point**	**Observation**
1.	Fixing of mounting structure	
2.	Prevent leakage of water due to rain?	
3.	Is the Orientation or tilting angle proper?	
4	Is pv string tight or loose	
5	Is the cable connection tight or looses	
6	After installation cleaned?	
7	Possible shadow from surroundings?	
8	Wiring from Module to Earth pit and to metal box properly installed or properly grounded?	
9	Other observation	

2. Visual inspection of Distribution Board

S.No	**Main Check Point**	**Observation**
1.	Fixing, wire connection and alignment proper?	
2.	Distance between DB, Inverter and Charge Controller as per drawing?	
3	Is the DB properly mounted	
4	Is the DB Properly grounded	
5	Protecting devices consisted in DB (2 ac Fuses, 1 dc fuses, -----)?	
6	After installation cleaned?	
7	Observation against possible damage from the surroundings?	
8	Installed safe place so as children or patients not touch?	
9	Other observation	

3. Visual inspection of Inverter Charge Controller

S.No.	**Main Check Point**	**Observation**
1.	Wire size proper, connections fix secure and proper align?	
2.	After installation cleaned?	
3	Is it functional at the time of inspection?	
4	Is it Properly grounded?	
5	Is it Out of reach of children?	
6.	Observation against possible damage from the surroundings?	
7.	Other observations	

4. Visual inspection of Battery

S.No.	**Main Check Point**	**Observation**
1.	Placed safe and all battery installed in box?	
2.	Wire connection fix and firm secure?	
3.	Wire size, connection and alignment done proper and as per drawing?	
4.	After installation cleaned?	
5.	Observation against possible damage from the surroundings?	
6.	Placed in ventilated box area?	
7	Is it at a place where no direct sun shine or rays can reach?	
8	Other observations	

5. Socket and lightings fixture

S.No.	**Main Check Point**	**Observation**
1.	Fix proper and firm?	
2.	How many sockets are installed?	
3.	How many lamps are installed is all functional at the time of inspection?	
4.	Wire size, alignment and connections proper?	
5.	After installation cleaned?	
6.	Observation against possible damage from the surroundings?	
7.	Lighting bulb suspends from ceiling and has uniform light intensity?	
8.	All light bulbs have separated on-off?	
9	Other observations	

6. Wiring and Casing

S.No.	**Main Check Point**	**Observation**
1.	Conduits fix and align proper?	
2.	Saddles (metal or plastic clamps and screws) at proper distance?	
3.	After installation cleaned?	
4.	Observation against possible damage from the surroundings?	
5.	Crack walls due to installation maintained proper?	
6.	Other observations	

7. Lightning Arrester and Earthing System

S.No.	Main Check Point	**Observation**
1.	Lightning arrester installed proper?	
2.	Lighting mast install at higher height than the building and the pv array?	
3.	Is the Connection with earthing rod proper?	
4.	Earthing rod grounded and backfilled with earthing chemical powder?	
5.	Installed components connected to the earthing?	
6.	Others	

8. Visual inspection of roof installation of pvmodlue

S.No	Main Check points	Observation
1	Is appropriate sealing made for every roof penetration?	
2	Is the support structure and roof tightly fixed?	
3	Exposition to wind and any other damage	

9. Inspection of Spare Parts

S.No.	Main Check Point	Observation
1.	fuses	
2.	Dc/ac fuses	
3.	AC ckt breaker	
4.	DC ckt breaker	
5.	Charge controller	
6.	Battery terminal connectors	
7.	CFL	
8.	LED	

10. Special Tools

S.No.	Check Point	Observation
1.	Digital Multimeter	
2.	Test light	
3.	Cleaning material for module	
4.	Set of wrenches ranging from 6 to 32	
5.	Set of screw drivers (different type and size) with handle	
6.	Other observation	

10. General

S.No.	**Check Point**	**Observation**
1.	Stickers at proper location	
2.	Training for End users	
3.	Manual and guideline to End users	
4.	Do & don'ts explained proper?	
5.	System aesthetically acceptable?	
6.	Other observation	