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Study on Local Manufacturing of Renewable Energy Technology Components in East Africa

Working Paper

prepared by

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Project Team

Project Advisor	Mr. Amit Kumar Dr. Ligia Noronha
Project Coordination	Mr. Anandajit Goswami
Technical expert (Biomass gasifier)	Mr. Sunil Dhingra Mr. N K Ram
Technical expert (Solar PV)	Mr. Debajit Palit

Disclaimer

The data collected and presented in this pre-feasibiliy report are based on primary survey data which are dependent on individual stakeholder responses during the time of the interview. The project team is not responsible for any biases, inadvertent errors in the responses that came during the primary survey.

For more details on the project:

Anandajit Goswami
T E R I
Darbari Seth Block
I H C Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail anandjit@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delh (0) 11

Abbreviations

AC	Alternating current
ACU	Asian Clearing Union
ADLI	Agricultural Development Led Industrialization
AGM	Absorbed Glas Mat
ASEAN	Association of Southeast Asian Nations
a-Si	Amorphous Silicon
BITs	Bilateral Investment Treaties
BoS	Balance of Systems
CdTe	Cadmium Telluride
CIGS	Copper Indium Gallium Diselenide
COMESA	Common Market for East and South Africa
CREEC	Centre for Research in Energy and Energy Conservation
DANIDA	Danish International Development Agency
DC	Direct Current
DSSC	Dye Sensitized Solar Cell
DTI	Directorate of Industrial Training and Sports
ECOWAS	The Economic Community of West African States
EEPCo	Ethiopian Electric Power Corporation
EREDPC	Ethiopian Rural Energy Develoopment and Promotion Centre
ERT	Energy for Rural Transmission
ETB	Ethiopian Birr
ETC	Ethiopian Telecommunication Corporation
EVA	Ethly-Vinyl-Acetate
F.O.B	Freight on Board
FDI	Foreign Direct Investments
GDP	Gross Domestic Product
GTZ	Deutsche Gesellschaft Technische Zusammenarbeit
GWh	Giga Watt Hour
IBSA	India, Brazil and South Africa
ICT	Information and Communication Technology
IGAD	Inter-Governmental Authority on Development
IREMP	Integrated Rural Electrification Master Plan
kWe	Kilowatt electricity
MDG	Millennium Development Goal
MEMD	Ministry of Energy and Mineral Development
MIG	Metal Inert Gas
MSMEs	Micro, Small and Medium Enterprises
MTOE	Metric tonne oil equivalent
MWh	Megawatt Hours
NEC	National Electric Code
NEPAD	New Partnership for African Development
NGO	Non-Governmental Organisation
NiCd	Nickel Cadmium
NREL	National Renewable energy Laboratory
OECD	Organisation of Economic Cooperation and Development
OPVs	Organic Photovoltaic Cells

P.O. Box	Post Office Box
PREEP	Promotion of Renewable Energy and Energy Efficiency Programme
PV	Photo Voltaic
R&D	Research and Development
REF	Rural Electrification Fund
RET	Renewable Energy Technology
SADC	South African Development Community
SHS	Solar Home Systems
SIDA	Swedish International Development Cooperation Agency
SIPs	Special Incentive Package Scheme
SLI	Starting, Lighting and Ignition
SMF	Seal Maintenance Free
SWERA	Solar and Wind Energy Resource Assessment
TERI	The Energy and Resources Institute
TICAD	Tokyo International Conference on African Development
TIG	Tungsten Inert Gas
TVGs	Technical Vocational Graduates
UEAP	Universal Electricity Access Program
UEAP	Universal Electricity Access Program
UMA	Uganda Manufacturers Association
UNCTAD	The United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
VAT	Value Added Tax
VRLA	Valve Regulated Lead Acid
Wp	Peak Watt

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Executive summary

Renewable energy technologies have a potential to meet the energy needs of various segments in East Africa owing to the possession of vast amount of renewable energy resources of East African countries. Currently most of the renewable energy technologies or technology components are imported. There is a need to build a reliance on local manufacturing of technology components to generate employment, development and increase self reliance of countries on indigenous technologies. Local development of renewable energy technology components can reduce the fossil fuel dependence of various sectors and can promote sustainable development.

Objective

In this context, the pre-feasibility study aims to assess the potential of local manufacturing of technology components of two renewable energy technology applications viz. biomass gasifier for heating applications and solar photovoltaic technology applications. The two East African countries that have been selected for the study are Uganda and Ethiopia. This is because Uganda is supposed to have biomass resources and Ethiopia has solar potential on the other hand. With this background, this pre-feasibility study aims to assess the potential of local manufacturing of technology components for biomass gasifiers in heating and thermal applications and for solar photovoltaic technology in various sectoral applications.

Findings

Biomass (firewood, charcoal, crop residues) is one of the major sources of energy in Uganda as it constitutes more than 90% of Uganda's energy consumption for cooking, water heating in rural, urban households, commercial buildings and institutions. Charcoal produced in non state land has contributed to biomass energy trading and has been useful for generating employment and tax revenue. The study reveals that the operational biomass gasifier systems in Uganda are working at a lower capacity. The sector is in a developmental stage and needs private participation, investments in the long run for up scaling and create large scale implementation of the technology. Many of the systems are yet to be commissioned and needs to establish a techno–economic viability. Generally the gasifiers are of three types – updraft, downdraft and cross draft based on the direction of air flow in the gasifier system relative to fuel flow. This pre-feasibility study shows that the cost of importing biomass gasifier systems for meeting cooking needs in Uganda is double the cost incurred for producing the system locally. Cost escalation in imported system happens owing to taxes, duties, transportation, packing and forwarding costs. This shows that there is a financial advantage in locally producing the biomass gasifier systems in Uganda for meeting cooking needs. For producing the system locally, metal fabrication would be required. Most of the metal fabrication units are around Kampala whereas some of them are in Jinja, Tororo and South Western industrial clusters. 90% of the manufacturing sector using biomass gasifier belongs to small and medium enterprises. More than 30% of these industries belong to agro based industries. Many systems in Uganda were installed under government programme and these systems are largely imported. Local manufacturing has to be consolidated and supported by technology transfer mechanism to facilitate localised technology development. Currently, R&D is being carried in the development of biomass conversion technologies. Training institutes are also present which are working on welding, machining and metal sheet fabrication. But there is a need to develop specialised training courses by vocational institutions. Such training can help in internalisation of use of high efficient systems, devices in household cooking and industrial applications viz. micro, small and medium enterprises where biomass gasifier technologies can be used. But for realisation of that, policies have to be designed by Ministry of Energy and Mineral Development (MEMD). MEMD budget can be allocated for facilitating technology transfer. Policies have to be implemented in Uganda to create linkages between R&D institutes. Linkage chain has to be established between plantation and biomass supply, processing and final technology that uses the feedstocks. Institutes promoting entrepreneurship has to be strengthened with the help of human resources from Southern countries. Proactive policies have to be designed for this exchange of human resources through South-South Cooperation measures that can finally help in entrepreneurship development in Uganda.

The other segment of the study dealing with solar photovoltaic applications in Ethiopia finds out that in Ethiopia, kerosene is the main source of lighting followed by firewood. Most of these kerosene requirements are met through imports. Other than this, dry cells are used as an energy source. Additionally, imported gensets of low capacity are sold to off grid markets. Solar PV technology are of the following types which are –a)Wafer based crystalline silicon solar cells, b) Thin film cells and c) Thin film silicon cells. Solar PV applications are of the following forms – a) Stand alone mode (solar home system, solar lanterns, solar pumps, street lights, micro power plant, solar charging stations), b) Grid connected mode, c) Roof top systems, d) Building integrated systems, e) Field array power plant.

The PV market in Ethiopia is in a growing stage. Demand for PV systems exists for communication, lighting, entertainment, vaccine refrigeration. During 1990s, early 2000s the demand was mostly for solar home systems (SHS) by NGOs. From mid 2000s, the demand for solar home systems has grown amongst the business and household community. Currently a major part of the SHS demand has been stemming from telecom sector. Additionally, demand has originated from small scale business, household and community. Demand from the household and commercial sector has been growing rapidly with the major part of it coming for lighting, TV set powering and mobile phone charging. Demand for solar home systems has been coming from government, NGOs, church organisations.

Solar is a secondary business for most of the equipment dealers. Market segment of PV comprises of – a) offgrid household and small business, b) institutional systems, and c) telecommunications. The national importer/distributor has been largely engaged in importing, assembling, sales and marketing. Solar PV systems are priced 2-3 times more than the price of the systems coming from Asian countries.

As of now, solar PV equipments are imported from Germany, U.S and Asia. Products from U.S, Germany are imported and they fetch a higher price. The imported modules are priced at $2.5 - $3.5 per WP that faces a 15% margin on freight, insurance followed by a 25% margin on surcharge, VAT, retain margin leading to a final product cost of $5.5 - $6.5 per WP. Most of the time these imported solar PV components are not of uniform quality. Strong, consistent supply chains between demand points and international suppliers doesnot always exist. There is a need to build upon the low technical know how of local end user because of whose lack of awareness substandard products are often imported. Further, import/customs duty has been waived off from imported solar systems. Many organizations involved in import of products are not able to reap benefits from the duty waiver as they are unaware about the technical specifications of the products. So, often the duties are paid to clear the consignments and such duties enhance the final cost of the product.

Components of solar PV modules are mainly assembled in Ethiopia. Complete assembling of SHS is being done by few local dealers, NGOs. There is a scope for capacity building, training of these local dealers. Plans of establishment of manufacturing plants are in place. Solar cell manufacturing can be a long term option for Ethiopia. In the short, medium term establishment of a solar module assembly line can be considered in Ethiopia. Ethiopia has battery manufacturing capacity and is in the process of manufacturing deep discharge batteries. In future, an existing company (Awash Battery Manufacturers) could be involved to manufacture tubular lead acid and VLRA batteries. Ethiopia doesn't have the capacity to create charge controller fabrication in the short term and it could be considered in long run. Solar lanterns could be initially imported, assembled which later on could be produced within the country. Major demand for the solar lanterns (CFL and LEDs) has been from the off grid segment. Also PV systems in many cases are supplied with storage units. Most raw materials are imported in Ethiopia for making solar modules. Use of hydropower for development of solar PV cells, engagement of local technicians could be some of the innovative measures in generating green sustainable cells in the PV segment in Ethiopia.

As of now, there is a supply constraint of raw material for production of solar modules owing to hard currency problem. SMF lead acid battery production can be initiated in the medium to long term in Ethiopia which can meet the demands of these products in Ethiopia and in neighbouring country markets like Sudan. Semi automated production line for solar lanterns can be more feasible option for Ethiopia and on an average a 5MW solar PV module assembly line can lead to a direct employment of 40 – 50 skilled persons. Thus in the short to medium term, solar module, lantern assembly line can be established. Additionally, in the long run, existing battery unit can be strengthened and more battery manufacturing units can be set up.

Way forward - through a common conclusion

So the prefeasibility study finds out that biomass gasifier for heating and thermal applications can be developed with the involvement of private sector participation in the short, medium term. This can start with the introduction of few demonstration projects. Development of skilled human resources for local manufacturing of technology components for biomass gasifier and solar photovoltaic applications is very much required to develop technological goods with better quality than what exists now. This can also generate local employment and income generation for the two technology applications as found out in the study. Local employment can happen through assembling of small capacity solar modules in Ethiopia and also through metal fabrication activity in biomass gasifiers in Uganda. However for a long term development of both the technologies, collaboration, partnership with countries of South Asia has to be established. This has to be supported by favourable South South Cooperation policies and country policies that give financial incentives for local manufacturing of technology equipments in both these countries.

Introduction

In the East African context, local development and enhancement of renewable energy technology components and systems has a large relevance as it could help in domestic capacity building. Local technology development can create jobs and can increase the livelihoods. Opportunity exists for tapping the renewable energy sources to provide clean energy services for households along with livelihood and revenue generation for local producers. Currently, many Renewable Energy Technologies (RETs) dealing with solar photo-voltaic, solar thermal, biomass and micro hydro are being imported from India and China to East African countries like Ethiopia, Uganda, Kenya and Tanzania. Capacity enhancement for development of renewable energy systems and components could generate larger multiplier effects for the countries of East Africa in terms of employment, and business opportunities. A local manufacturing of balance of system parts and components of the technologies through integration with the indigenous needs and conditions could contribute in effective applications of these renewable energy technologies.

Currently, in some of the East African countries like Uganda, Ethiopia far-reaching diffusion of biomass gasifier and solar PV technology RETs faces institutional, human resource, supply chain, technical and financial barriers. One of the hindering factors against this wide spread diffusion is the high initial cost, limited penetration, scarce availability of RET-based system components, spare parts and systems compared to conventional energy technology choices. Some of these barriers in case of biomass gasifier technology applications in Uganda include lack of skill, absence of companies who are willing to diversify into different technological products, lack of willingness by high end companies to get into fabrication, absence of financial incentives for the metal sheet fabricators, technology developers. Biomass gasifier technology in Uganda has a long run potential if these barriers are overcome. But to realise that streamlining of policies and their faster implementation with the help of MEMD has to be done. This would need to be further complemented by active involvement of private players. Once this is implemented, technology could be developed locally and can reap the benefits of local low cost of technology development in comparison to the imported products.

Similarly for PV systems, skill building, local assembling of modular units could be started in the medium term with financial incentives that leverage easy credit access. Supply constraints faced by the dealers in the Ethiopian PV market needs to be reduced for smoothening that local assembling. One of the ways to do is through reduction of the hard currency problem. Also standards need to be established to have a quality control of the imported products from Germany, China and India into Ethiopia. In the long run, battery manufacturing units have to be established. Local skill development to manufacture products in these units can not only create direct and indirect jobs but can also help in production of low cost products for the local and neighbouring markets in Sudan. In the long run this can help in reducing the reliance on imported products to cater the demand in the domestic market.

All of these have to be done with the help of policies and their faster implementation that would involve:

- Involvement of broad range of energy service providers,
- Enhancement of a combined technological and financial support measures to facilitate local renewable energy technology and system development,
- Use of financial instruments like loans, partial guarantees, revolving funds, group

guarantees (like the ones provided by women self help groups), and equipment leasing.

Objective

The main objectives of this study are:

- To identify and map components for solar photovoltaic applications in Ethiopia and biomass gasifiers for heating applications in Uganda, which could be manufactured locally.
- To prioritise these components over the short, medium and long term, in order to prepare the ground for a subsequent large scale effort.
- To assess the scope of strengthening the capacity of the manufacturing sector to produce the aforementioned biomass gasifier systems/components for heating applications in Uganda and solar photovoltaic applications in Ethiopia.
- To assess the competitiveness of the locally produced technology components and systems.
- To provide an indicative and directional estimate of costs and benefits of manufacturing complete systems/ components in Uganda and Ethiopia.
- To identify the relevant initiatives including measures facilitating South-South Cooperation that could contribute towards local small and medium scale manufacturing base development of renewable energy technology and balance of system components.

Methodology

The whole exercise comprised of the following key elements:

- Literature review and secondary research.
- Stakeholder consultations to assess the possibilities of local manufacturing of systems / components.
- Visit to units across different region.
- Meeting and interaction with key stakeholders Ministries, industry bodies /associations.
- Analysis of information/data.
- Annexure B-1 provides the survey questionnaire and Annexure B-2 provides the list of respondents for the solar PV component of the study.

Structure of the report

This report consists of detailed assessment of both technologies & relevant policy recommendations, cost benefit analysis, mapping and prioritising. Detailed analyses were carried out to determine the nature and type of discrete components that could be produced locally by the manufacturers over the short, medium and long term. While carrying out this exercise, an analysis of the competitiveness of these technologies and market potential of these technologies was conducted. The cost competitiveness is then compared vis-à-vis the imported cost and the cost of local fabrication of components.

The report has been divided into two sections, Section-A dealing with "Biomass Gasifier for heating in Uganda", and Section-B describing the "Solar Photovoltaic applications in Ethiopia" and a consolidated project summary at the end.

The different chapters given hereunder are:
Chapter A-1: Energy situation in Uganda
Chapter A-2: Biomass gasifier technology description
Chapter A-3: Metal processing industries in Uganda
Chapter A-4: Market potential of biomass gasifier for heating applications in Uganda

Chapter A-5: Identification of policy interventions
Chapter A-6: Key findings and recommendations
Chapter B-1: Energy situation and manufacturing sector in Ethiopia
Chapter B-2: Solar PV technology
Chapter B-3: Solar PV in Ethiopia
Chapter B-4: Options for local manufacturing of PV components
Chapter B-5: Key findings and way forward
Consolidated project summary

SECTION **A: Biomass Gasifier for heating in Uganda**

A-1 Energy situation in Uganda

1.1 Uganda country profile

Uganda is a land-locked country lying on the equator in central Africa. It shares borders with Sudan, Democratic republic of Congo, Rwanda, Tanzania and Kenya. 20% of the country is covered by inland lakes. The rest ranges through tropical rain forest to savannah with mountains on the western border. It lies between latitudes 4012' North and 1029' South and longitudes 29035'East and 35000'East; Area: 236,040 km2 (199,710 km2 land and 36,330 km2 water) Uganda has a population of about 26.8 million, according to the country's bureau of statistics. The population growth rate is 3.3 percent per annum, a figure higher than other countries in the region.

Ugandan economy relies heavily on agriculture; agriculture is the basis of livelihood for 80% of the population (Figure-A-1). The major export crop is coffee, with some revival of tea, tobacco and cotton production. Uganda's economy has performed well in recent years, averaging around 6% annual growth between 1998 and 2005. Sound macro-economic policies contributed to an 8.6% growth rate in fiscal year 2007-2008, compared to 7% in FY 2006-2007.

Figure A-1 Map of Uganda

Agriculture is one of the country's main industrial sectors, employing 80% of Uganda's workforce, and made up 31.4% of the country's GDP in 2002 that totalled US$5.9 billion. The main agricultural crops that are cultivated are cassava, sweet potatoes, plantains, millet, sorghum, corn and pulses. Industry and services made up 22.7% and 45.9% of GDP respectively. The main industry sectors in the country are mostly agro-processing oriented, made up mostly of fish processing, sugar, tea, cooking oil, dairy processing, breweries and soft drinks. The manufacturing of textiles, paper products, as well as, tobacco processing also takes place.

1.2 Energy situation in Uganda

Uganda has very limited access to grid power i.e. less than 10% of the population are connected to grid, in which 3% recede in rural area's and are heavy dependent on fuel wood for to meet their domestic energy needs. Fuel Wood is the dominant energy source accounting for 80 per cent of the total energy consumed in the country. Wood fuel is consumed either as charcoal (largely consumed in urban areas) or firewood (mostly used in rural areas).

Biomass (firewood, charcoal and crop residues) plays a very significant role in Uganda's energy supply. It constitutes over 90% of total energy consumption in the country. It provides almost all the energy used to meet basic needs of cooking and water heating in rural and most urban households, institutions and commercial buildings. Biomass is the main source of energy for rural industries. Trading in biomass energy, especially charcoal contributes to the economy in terms of rural incomes, tax revenue and employment. It saves foreign exchange, employs 20,000 people and generates USh.36 billion (US$ 20m) per year in rural income. Fuel wood requirements have contributed to the degradation of forests as wood reserves are depleted at a rapid rate in many regions. Charcoal consumption increases at a rate close to that of urban population (6% per annum). Charcoal is generally produced on non-state land. Biomass (bagasse from sugar processing industry) is also used to produce electricity and steam (cogeneration).

Most of the traditional energy technologies (wood and charcoal stoves and charcoal production kilns) currently used in Uganda are inefficient. Several initiatives to conserve biomass resources have been undertaken by Government and the private sector, including NGOs. They include the promotion of improved stoves, as well as aforestation. However, the impact of these efforts is still limited.

A drop in the water level of Lake Victoria in 2005/06 led to a major reduction in the nation's electricity supply and an energy crisis. Uganda has rapidly expanded and diversified its energy supplies away from its near exclusive reliance of two hydroelectric facilities, but still has a supply shortfall. New energy hydroelectric and fossil fuel electric generating facilities are projected to come online over the next few years. Oil has recently been discovered in the western part of the country which will begin producing in 2009/10. These developments should help Uganda sustain the brisk economic growth experienced during much of the past two decades and broaden the access to modern energy supplies. However, growing Uganda's energy supplies include significant financial and environmental challenges.

1.3 Biomass gasifier in Uganda

As discussed above, biomass is the main resource to meet the energy needs of various domestic as well as industrial sectors of the country. Currently, biomass is used in highly inefficient stoves and ovens, the adoption of biomass gasifier systems in these sectors would reduce significant amount of biomass consumption, at the same time it will improve the local working environment. Presently, the biomass gasifier systems are operational in tea estates for drying and in boarding schools for institutional cooking. The gasifiers for electricity generation are also being implemented at educational institutions in Uganda. Details of the same are discussed below:

1.3.1 Finlays Tea Company

One biomass gasifier based power generation plant is operational at Finlays Tea Company since 2006. The capacity of the system is reported around 200 kWe and the system is operating at lower capacity.

1.3.2 Demonstration of pilot Biomass Gasifier systems under Energy for Rural Transformation (ERT) program

A long-term programme for improving access to modern energy, Energy for Rural Transformation (ERT), has been implemented by the Government of Uganda, with the Ministry of Energy and Minerals Development as the lead agency, and the World Bank, under the aegis of the Africa Rural and Renewable Energy Initiative (AFRREI) in the Bank's Africa Energy Unit. ERT is a ten year programme divided into three tranches, roughly equal in terms of time:

First phase: development of the framework and carrying out pilots;
Second phase: accelerating investments and build upon lessons learned; and
Third phase: scale-up and institutional build up.

The purpose of the ERT programme is to develop Uganda's rural energy sector so that it makes a due contribution to bringing about a rural transformation. For this purpose, the project includes cross-sectoral synergies, while remaining firmly anchored within the energy sector. ERT's cross-sectoral linkages build upon facilitating access to energy to be used for the benefit of the rural population. One of the components under ERT programme is to establish demonstration projects in Uganda:

- Biomass gasifier based power plant of 150 kWe capacity at Nyabyeya Forestry College.
- Biomass Gasifier for cooking application (50 kWth) in Kings' College Budo, Kampala
- Demonstration of biomass gasifier for electricity generation at Khyambogo.

1.3.2.1 Biomass Gasifier for power generation at Nyabyeya Forestry College

Under this demonstration project two biomass gasifier systems for power generation of the capacities of 100 kWe and 50 kWe were procured. One of the specific objectives of this project is to demonstrate the technical feasibility of the biomass gasification technology at Nyabyeya Forestry College (NFC) to supply electricity to NFC campus for teaching and R&D set up, saw-mill, wood workshop, mechanical workshop, campus staff quarters and administrative block and surrounding trading centres. The biomass gasifier system has been supplied at site but yet to be installed and commissioned.

1.3.2.2 Biomass gasifier for cooking applications at Kings' College Budo campus

The specific objective of this project is to demonstrate the technical feasibility of the biomass gasification technology for thermal applications in Uganda. A pilot demonstration plant was established at King's College Budo (KCB) in the kitchen for preparation of breakfast, lunch and dinner for the students. The system was installed but not yet commissioned.

1.3.2.3 Biomass gasifier for power generation at Kyambogo University

A 10 kWe biomass gasifier based power generation system has been supplied to the institute. This system was to be used mainly for demonstration and training purposes. The system is yet to be commissioned.

It is recommended that Ministry of Energy and Mineral Development (MEMD), along with Makerere University, carry out the performance monitoring of these locations and obtain performance data to establish the techno-economic viability of the technology.

A-2 Biomass gasifier technology description

This chapter discusses the details about biomass gasifier technology, types of biomass gasifiers, different components of biomass gasifier system, manufacturing process and cost comparative analysis of local production of biomass system.

2.1 Biomass Gasifier technology description

Biomass gasification is a process through which solid biomass material is subjected to partial combustion in the presence of limited supply of air or oxygen. The product is a combustible gas mixture known as ‘producer gas. The combustion of biomass takes place in a closed vessel, normally cylindrical in shape, called ‘gasifier’. Producer gas typically contains carbon mono-oxide (20-22%), hydrogen (12-15%), methane (2-3%), carbon dioxide (9-11%) and nitrogen (45-50%). Producer gas has a calorific value ranging from 1000-1100 kcal/m^3 (5500 – MJ/m^3) depending upon the properties of biomass used.

Biomass gasifier is usually an upright cylindrical unit made of mild steel with air tuyers in the combustion zones usually made of stainless steel. Many designs of biomass gasifiers have been developed and based on the method of gas-solid contact, the gasifiers are classified as fixed-bed for high density fuels in small and medium capacities, whereas fluidised bed gasifier is generally applied for low density fuel at lower temperatures and for high capacities. The other type of biomass gasifier is based on direction of flow of air/gas which are classified as down-draft, up-draft and cross-draft type gasifiers respectively.

2.1.1 The Gasification process

Gasification of biomass takes place in four distinct stages i.e., drying, pyrolysis, oxidation/combustion and reduction in that order. Biomass is fed at the top of the hopper. As the dried biomass moves down, it is gradually heated up. Biomass starts releasing volatiles at above 200° C and continues until it reaches the oxidation zone where the pyrolyzed biomass is completely consumed releasing ash. Once temperature reach 400° C, the structure of wood breaks down releasing combustible gases, along with water vapour, methanol, acetic acid and tars as part of the pyrolysis process. These products of pyrolysis are drawn towards oxidation zone, where a predetermined quantity of air is supplied to promote combustion in order to raise the temperature. A portion of the pyrolysis gases and char burns as the temperature rises from about 900° - 1200° C in the oxidation zone. Partial oxidation of biomass by gasifying agents (air or O_2) takes place in the oxidation zone resulting in producer gas, cracked and un-cracked pyrolysis products, and water vapour (steam) which pass through the reduction zone containing mostly charcoal. The principal chemical reactions taking place in a gasifier are given in Table A-2.1 below:

Table A-2.1 Principal reactions in a gasifier

Reaction type	Reactions	Enthalpy (kJ/mol)
Devolatisation	C + heat → CH_4+condensable hydrocarbons + char	
Steam-carbon	C + H_2O+ heat → $CO+H_2$	131.4
Reverse Boudouard	C + CO_2 + heat → 2CO	172.6
Oxidation	C + O_2 → CO_2 + heat	-393.8
Hydrogasification	C+ $2H_2$ → CH_4 + heat	-74.9
Water gas shift	H_2O + CO → H_2 + CO_2 + heat	-41.2
Methanation	$3H_2$ + CO → CH_4 + H_2O + heat $4H_2$ + CO_2 → CH_4 + $2H_2O$ + heat	-74.9

In the above reactions, de-volatilisation takes place in the pyrolysis zone, oxidation in the oxidation zone and the rest distributed in the partial oxidation and reduction zones. The low heating value of producer gas (about 10-15% of natural gas), is mainly due to the diluting effect of nitrogen present in the partial combustion/oxidation air. An efficient gasifier produces a clean burning producer gas over a range of selected operating conditions. If all the above-mentioned processes take place efficiently, the energy content of the producer gas should lie between 70-78% of the energy content of the biomass consumed in a gasifier.

The gasification process is mainly influenced by two parameters: properties of the biomass and the gasifier design. Biomass properties such as energy content, density, moisture content, volatile matter, fixed carbon and ash content and also the particle size and geometry of biomass affect the gasification process. While designing a gasifier, the design of the oxidation zone is most important as the quality and quantity of the producer gas depends on it. Complete conversion of biomass depends on the residence time of biomass in the oxidation and reduction zones. Size, geometry, location, and number of air tuyers are the critical parameters for the design of gasifiers.

2.2 Types of gasifier

According to the flow of gas/air introduced into the gasifier, they can be classified as:

a) Updraft
b) Downdraft gasifier
c) Cross draft gasifier

2.2.1 Updraft gasifier

In the counter-current-moving-bed- reactor, also called the updraft gasifier, the air flows counter to the downward fuel flow and enters into the gasifier from below the grate and flows in the upward direction within the gasifier (Figure A-2.1). An updraft gasifier has distinctly defined zones for partial combustion, reduction, and distillation/Devolatilisation. The gas produced in the reduction zone leaves the gasifier reactor together with the pyrolysis products and the steam from the drying zone. The resulting combustible producer gas is rich in hydrocarbons (tars) and, therefore, has a relatively higher calorific value.

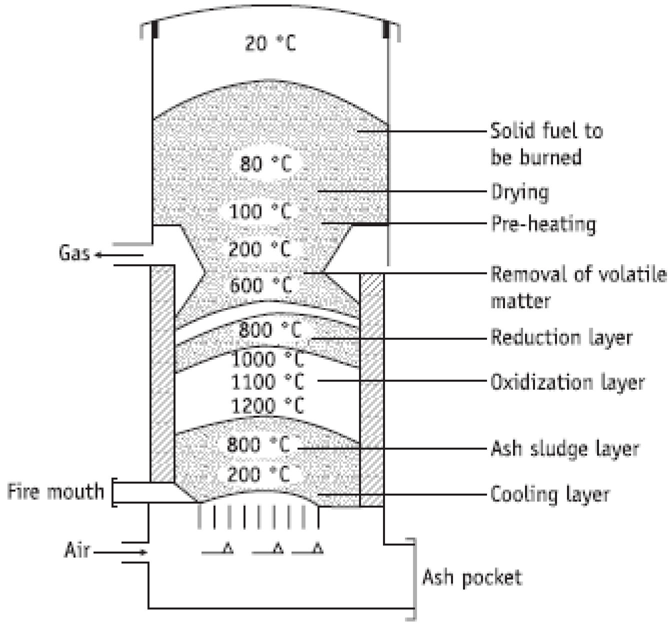

Figure A-2.1 An Updraft gasifier

2.2.2 Downdraft gasifier

The most common gasifier is the downdraft gasifier or co-current type. In this gasifier, the pyrolysis zone is above the combustion zone and the reduction zone is below the combustion zone. Fuel is fed at the top. The flow of air is down ward through the combustion and reduction zones (Figure A-2.2). The term co-current refers to the fact that the movement of air is in the same direction as that of the fuel.

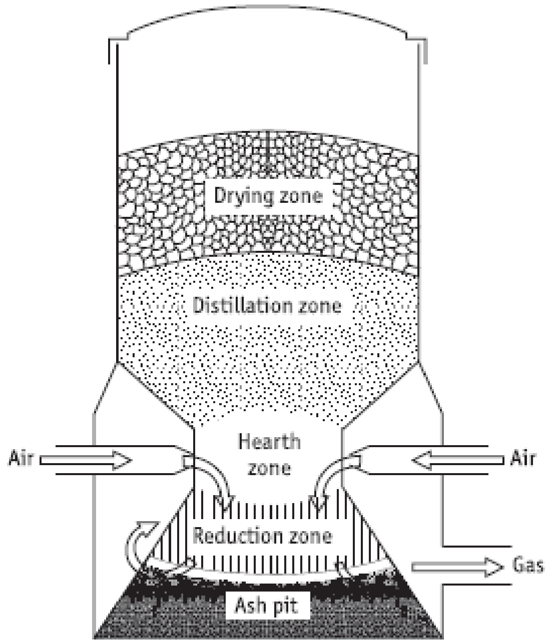

Figure A-2.2 Downdraft gasifier

The essential characteristics of the downdraft gasifier is that it is designed so that the tars given off in the pyrolysis zone travels through the combustion zone, where they will be broken down or burned (provided the gasifier is working properly). As a result, energy is released and the mixture of gases in the exit stream is relatively clean. The arrangement of combustion zone is thus a critical element in the downdraft gasifier.

2.2.3 Cross draft gasifier

In a cross-draft gasifier, air enters from one side of the gasifier reactor and leaves from the other side (Figure A-2.3). Cross-draft gasifiers have very few applications and have really any distinct advantage other than good permeability of the bed.

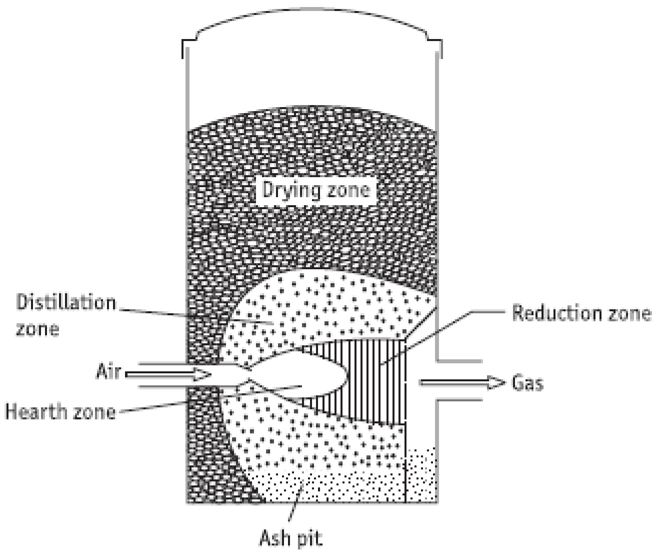

Figure A-2.3 Crossdraft gasfiier

2.2.4 Biomass gasifier based thermal systems

The line diagram of general scheme of biomass gasifier for heat applications explaining the working arrangement is shown in Figure A-2.5 in a subsequent page. A biomass gasifier for heat application is simple in construction. It consists of a biomass gasifier, a blower, and a burner with a furnace. For heat applications, any of the aforementioned three types of biomass gasifiers can be used. The producer gas produced from the gasifier can be efficiently used with a good degree of control to meet heat demands in ovens/burners, boilers or kilns for thermal applications.

2.2.5 Biomass gasifier based power generation systems

The line diagram of General scheme of biomass gasifier based power system explaining the working arrangement is shown in Figure A-2.4. A gasifier based power generation system consists of a biomass gasifer that converts the solid fuel into combustible gas. The hot combustible gas coming out the gasifier carries impurities like dust particles and tar vapours, which needs to be cleaned in the cleaning train before supplied to the IC engine for power generation. In general biomass gasifier is coupled to a series of filters such as gravity filters wet scrubbers, cyclone separators and bag house filters. A paper filter is used as a safety filter to ensure that the clean gas with permissible levels of tar and dust particulate supplied to the engine. The gas and air mixture is introduced at the air intake manifold of the engine. Valves are provided both for the air and the gas in order vary the quantity of gas and air to obtain the optimum mixture.

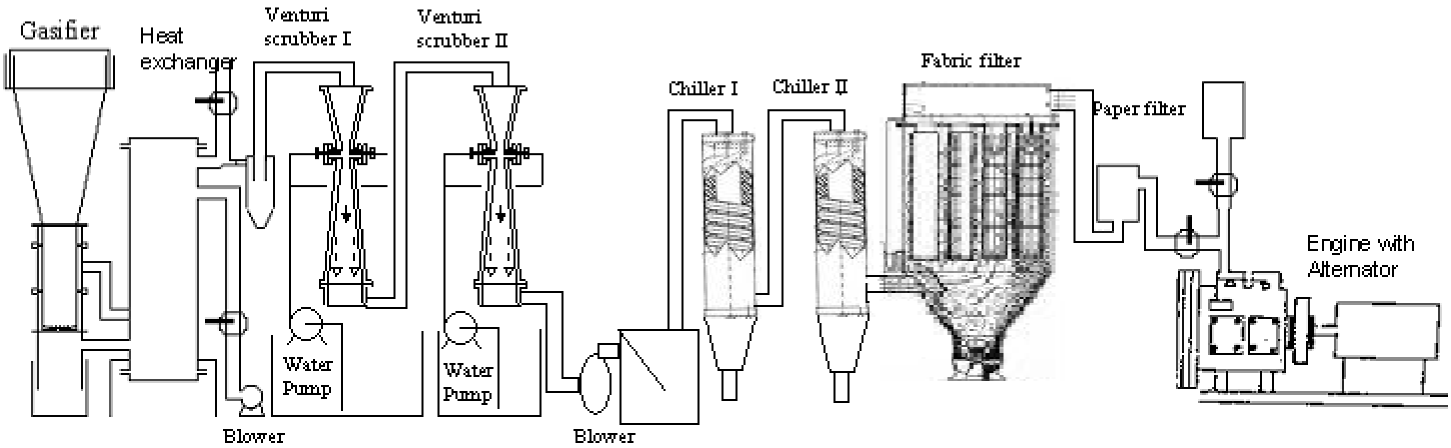

Figure A-2.4 General scheme of biomass gasifier based power system

The gas air mixture is intern supplied to a natural gas engine, which converts the chemical energy in the gas to mechanical energy by rotating a shaft. The engine shaft is intern coupled to the shaft of an alternator that converts the mechanical energy into electrical energy. The electrical energy so produced by the alternator is distributed through electrical conductors to the connected load to power the Bulbs, Motors & other electrical appliances.

2.3 Manufacturing

Manufacturing of biomass gasifier involves different processes such as preparation of detailed fabrication drawings of the components, developing sheet metal profiles, cutting of the sheet metal, bending and rolling of the metal, welding, high temperature casting of combustion zone, piping and ducting arrangement, fitting of valves and burner, grinding and finishing process, insulation of the hot surfaces, painting and buffing processes.

The different components of a typical biomass gasifier are described in Figure A-2.5. In biomass gasifier manufacturing process a team of technicians with different skills sets includes; trained welder (thin and heavy sections), fitter, high temperature casting and thermal insulation. A Table A-2.2 giving different component details of biomass gasifier for heat applications is given below:

Table A-2.2 Component details of biomass gasifier for heat applications

S No	Component Name	Material used	Manufacturing processes involved	Type of skill needed
G1	Reactor	Stainless steel	Sheet cutting, bending and welding processes	Welder
G1	High temperature casting and thermal insulation	Castable cement/ insulating bricks	Mixing, compacting and curing	Casting and curing expertise
G2	Hopper	Stainless steel / Mild steel	Sheet cutting, bending and welding processes	Welder
G3	Grate Assembly	Casting/ Stainless steel	Rod bending and welding processes	Welder
G4	Ash pit	Stainless steel	Sheet cutting and welding processes	Welder
G5	Blower	Stainless steel / Mild steel	Bought out item	Fitter
G6	Piping High temperature Cold line	Stainless steel/ Mild steel	Fitting	Fitter
G6	Ducting	Stainless steel / Mild steel	Sheet cutting and welding processes	Welder
G7	Gasifier lid	Stainless steel / Mild steel	Sheet cutting and welding processes	Welder
G8	Burner	Stainless steel	Sheet cutting and welding processes	Welder
Apart from the above, following are the additional components required for building a gasifier system				
A	Furnace	Fire bricks	Construction of furnace	Trained mason
B	Insulation & cladding	Ceramic blanket/ Glass wool	Pipe insulation & cladding	Insulation skills
C	Air and gas valves	GI ball valves	Bought out items	
D	Biomass cutter	High speed steel cutter	Bought out item s	
E	Instruments CO alarm Moisture meter Temperature indicators		Bought out item s	

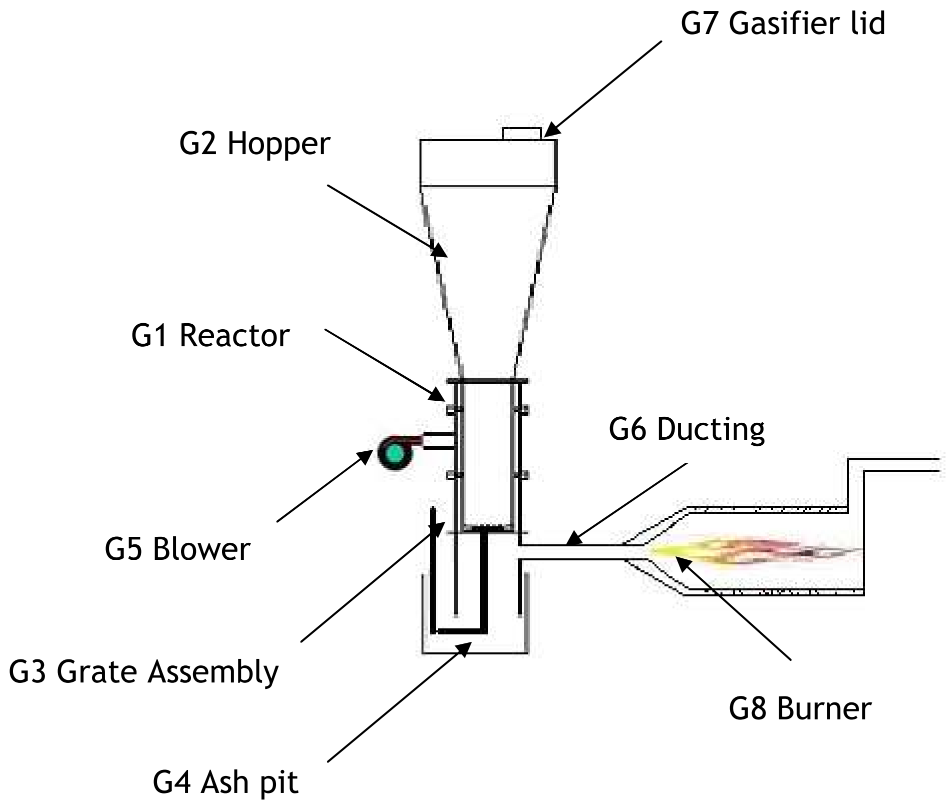

Figure A-2.5 Schematic diagram of the biomass gasifier for heat applications

2.4 Cost analysis

An indicative cost estimate of a typical biomass gasifier has been made in this pre-feasibility study based on input material costs used in the manufacturing process. The gasifier manufacturing process requires different raw materials such as mild steel, stainless steel and insulating materials. Most of the materials (sheet metal, steel rods, pipes and valves) are available locally but items like high temperature insulation, blowers, ceramic blanket and glass-wool insulation are not readily available in the local market in Uganda. The prices of different available materials were obtained from the local market and compared with the Indian market (See Table A-2.3). It can be seen from the table while the variation in the stainless steel sheet is only 5% but the variation in mild steel sheet is as high as 50%. In structural steel, the variation is about 20-30%. In case of welding rods and other bought out items, the variation is more than 60%. Further, a comparison of manpower costs under different category of skill workers is also made and given in Table A-2.4.

Table A-2.3 Comparison of material cost

	India		*Uganda*		% Increment
Material/Item	**RS/kg**	**USD**	**USh/ kg**	**USD**	
Mild steel sheet	38	0.844	4400	2	51
Mild steel sheet	38	0.844	4400	2	47
Stainless steel	200	4.444	11000	5	5
C channel (Mild steel)	46	1.022	2200	1	22
I section (Mild steel)	46	1.022	4400	2	33
MS Angle (Mild steel)	33	0.733	2200	1	32
G.I. valve (Diameter6")	2500	55.556	382800	174	68
Welding Rod (Mild steel)	66	1.467	8800	4	63
Mild steel pipe	50	1.111	4400	2	26

Table A-2.4 Comparison of wage structure under different category of skilled workers

Technical Trade	***Man power cost***		***Man power cost***	
	India/month	***Uganda /month***	***India/month***	***Uganda/month***
	INR	USh	USD	USD
Welder	12000	653400	267	297
Fitter	15000	490600	333	223
helper	12000	261800	267	119
Supervisor	21000	1144000	467	520
Engineer	36000	1797400	800	817

A comparative analysis of locally produced biomass gasifier system with imported system has been made. For this purpose, the estimated cost of a 30 kg/h capacity biomass gasifier for cooking application has been worked out based on bill of materials, manpower cost and prevailing taxes and given in Table A-2.5. The estimated cost of the locally produced system was compared with biomass gasifier system of 30 kg/h capacity recently imported from India under the ERT programme of MEMD, which has been set up at Kings College Budo for cooking applications.

The cost of the system imported for heating application (cooking needs) at Kings College Budo was approximately USh 44 million (USD 22,000), which works out to be almost doubled than the expected cost of the locally produce system on account of higher costs towards taxes and duties, transportation costs, packing and forwarding, etc. Hence, there is a big scope for reducing the overall cost of the biomass gasifier system through local production.

Table A-2.5 Approximate cost estimate of biomass gasifier system for heat applications (30 kg/h capacity)

Particulars	Amount in USh	Amount in USD
Material cost	8034400	3652
Manpower cost	4888400	2222
Installation	1100000	500
Taxes	1335400	607
Profit	6461400	2937
Total	21819600	9918

A-3 Metal Processing industries in Uganda

This chapter provides an overview of Uganda's manufacturing sector, in particular, manufacturing of metal products.

Manufacturing sector in Uganda is still small. Most of the industrial and metal fabrication units are currently centred in and around Kampala. The balance of units is spread across the country in Jinja, Tororo and in the South Western industrial clusters. Capital goods industrial activity is still very low and similar to the manufacturing activity. Small and medium enterprises account for over 90%[1] of the manufacturing sub-sector with 39% of these in agro based industries.

It is estimated that 30%[2] of manufacturing of metal products' fabrication industries originate from local investors and rest 70%[2] is invested by investors from UK, Kenya and India. Iron industry in Uganda registered a growth rate of more than 20%[3] whereas steel industry grew at a rate of 30% annually. Construction and industrial fabrication in the country has contributed to high domestic consumption of steel and other raw materials. Further, most of iron and steel raw materials are imported from developing countries like South Africa, India and China. The regional distribution of manufacturing businesses in Uganda can be seen from the Table A-3.1 below.

Table A-3.1 Regional distribution of manufacturing businesses

Industry	Kampala	Central	East	North	West	Total
Processing of meat, fish, and diary products	23	19	18	13	19	92
Coffee processing	21	4	33	1	36	185
Grain milling	190	98	193	39	79	599
Tea processing	2	8	3	2	23	38
Bakery and manufacture of other food products	93	45	25	8	32	203
Manufacture of beverages and tobacco	51	12	10	6	4	83
Manufacture of textiles and leather products	80	33	47	26	34	220
Sawmilling, printing and publishing	275	35	26	19	30	385
Chemical and chemical products	66	8	7	-	2	83
Manufacture of plastics	60	37	47	2	32	178
Manufacture of metal products	263	79	55	32	55	484
Manufacture of furniture and others manufacturing	250	151	137	51	141	730
Total	1,374	619	601	199	487	3,280

Source: National Industrial Sector Startegic Plan 2009/10 – 2013/14

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[1] National Industrial Sector Strategic Plan 2009/10 – 2013/14
[2] Report on Iron and Steel Profile by Uganda Investment Authority

It can be seen from the above table that there are more than 484 units under the category of manufacturing of metal products.

3.1 Discussions with stakeholders

The project team, along with local partner, identified key stakeholders (see Table A-3.2) with whom consultations were held during the course of the project. A partial list of stakeholders is given below:

Table A-3.2 A list of stakeholder organisations, excluding sheet-metal fabrication industries

S.No	Organisation	Name / Designation
1	Ministry of Tourism, Trade & Industry	Mr. Hon. Eng. Samuel Ssenkungu, Commissioner, Industry & Technology
2	United Nations Industrial Development Organization	Mr. Bruno Otto, Head of UNIDO Operations in Uganda
3	Uganda Manufacturers Association	Mr. Robert Mawanda, Communication & Business Support Officer Mr. Mubaraka Nkuutu Kirunda, Director membership services
4	Ministry of Energy and Mineral Development	Mr. James Baanable Isingoma, Ag. Comm. energy resource department Mr. Michael Ahimbisibwe, Senior Energy Officer
5	Centre for International Migration and Development	Mr.Karsten Bechtel, CIM expert at CREEC
6	GTZ, Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP)	Mr. Leonard Mugerwa, Technical Officer, Stoves / Solar Energy
7	Department of Civil Engineering, Makerere University	Eng. Dr. Albert I. Rugumayo
8	Ministry of Education and Sports, Nakawa Vocational Training Institute	Mr. Musoke Matovu A.K., Principal

A brief summary of the discussions held with key stakeholders is complied and given below:

Various stakeholders were interviewed for the study which comprised representatives from Ministry, UN agencies, Manufacturers Association, Bilateral organisation and Technical University. Based on the feedback from stakeholders, it emerged that the systems installed in Uganda under the government programme are mostly imported from India. So there is a need to develop local manufacturing facilities to reduce this import dependency on other countries for technology. This has to be further supported by a technology transfer mechanism.

Currently, R&D is ongoing in biomass conversion technologies. Training institutes are in place, which are working on welding, machining and fabrication of metal sheets. These institutes are providing access to their facilities for the local industries engaged in sheet metal fabrication work. In spite of that there is a need for creating specialised training courses that would suit the needs of the industry. Such training courses can be started by vocational institutions.

Presently, most of the active sheet metal fabricators/manufacturers are registered members of UMA. Out of the 57 registered members, only 21 are associated with steel fabrication meeting the needs of the construction industry, 9 are engaged in production of aluminium structures and 5 amongst the registered members are steel vendors processing iron ore for roofing and structural requirements.

3.2 Detailed survey of manufacturing industries

The project team prepared a detailed questionnaire (see Annexure A-1) to assess the capability of different manufacturers, their existing product line, technical capabilities in terms of design, production, quality assurance, engineering practices, managerial, marketing, and financial capability. The project team met all the 16 short listed manufacturers and collected information. A list of industries surveyed during the study is given in Annexure A-2.

3.3 Key findings of the survey

Based on the information collected and discussions held with shortlisted manufacturers, an assessment of the manufacturers on different parameters has been made and given in Table A-3.3.

3.3.1 General findings of the manufacturing sector survey

- Most of the high-end fabrication units catering to industrial and infrastructure related projects have no interest in diversifying into new products and markets.
- Mid sized companies dealing in fabrication of sheet metal products have shown interest to venture into gasifier market.
- Most of the industries indicated that lack of skilled manpower in the country is the major barrier for expansion.
- Currently there are no local manufactures of gasifiers in Uganda.
- Metal fabrication industry is very small, and caters to the market demands.
- Most of the products are repeat orders. The marketing capabilities of many companies are largely un-proven. Occasional participation in trade fairs are ways of expanding customer base.

The gasifier manufacturing process consists of a number of components / parts that require different fabrication skills and equipments. Based on the above analysis and discussion, it is recommended to initiate future dialogue with the following set of industries in Uganda:

- Engineering Solutions (U) Limited
- Ramanand and Company limited
- Pioneer Engineering Works
- Welding Services
- JBT Engineering Works Limited
- Suman Engineering Construction Company

Table A-3.3 Assessment of capabilities of the shortlisted sheet metal fabrication industries in Uganda

	High turnover industries				Medium turnover industries				
Specifications	Steelworks Limited	Casements (A) Ltd	Victoria Engineering Ltd	David Engi-neering	Suman Engineering Construction	Rama Nand and Company Ltd	Pioneer Engineering Works	JBT Engi-neering Works Ltd	Specialised Welding Services Ltd
Technical									
Mild steel fabrication	Very Good	Fair	Good	Good	Good	Good	Fair	Good	Good
Sheet metal fabrication	Very good	Fair	Good	Good	Very good	Good	Fair	Good	Very Good
Stainless steel fabrication	Good	Low	Low	Low	Low	Low	Low	Good	Very Good
Machining accuracy	Good	Good	Very Good	Out-sourced	Good	Good	Low	Low	Outsourced
Suitability of equipment	Very Good	Fair	Good	Fair	Fair	Good	Fair	Good	Good
Skills of workforce	Good	Fair	Good	Good	Good	Good	Fair	Fair	Very Good
Engineering design skills	Good	Fair	Good	Low	Low	Fair	Low	Fair	Good
Bringing 'concept to reality'	Good	Good	Good	Fair	Fair	Good	Fair	Fair	Good
Ability to develop long-term	Good	Good	Good	Low	Fair	Good	Fair	Good	Good
Dependence upon proprietor	Low	Low	Low	Low	High	Low	Medium	Low	Low
Emphasis on training	Very Good	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Very Good
Focus on quality of product	Good	Low	Good	Low	Low	Low	Low	Low	V.Good
Marketing									
Knowledge of gasifier market	Low	Low	Low	Low	Low	Low	Low	Low	Low
Perceived marketing ability	Good			Fair	Fair	Fair	Fair	Fair	Fair
Ability to sell concept	Good			Fair	Fair	Fair	Fair	Fair	Good

	Low turnover industries						
Specifications	**John Lugendo & Co Ltd**	**Uganda Joinery & Steel**	**Nakawa Vocational Training Institute**	**Mobile Agricultural & Technical Services Ass**	**Engineering Solutions**	**Tonnet Agro Engineering**	**Bansal Engineering Works**
Technical							
Mild steel fabrication	Fair	Fair	Good	Fair	Fair	Fair	Fair
Sheet metal fabrication	Fair	Good	-N A-	Fair	Fair	Fair	Fair
Stainless steel fabrication	Low	Low	Low	Low	Low	Low	Low
Machining accuracy	Low	Low	Good	Low	Low	Low	Low
Suitability of equipment	Fair	Fair	Very Good	Fair	Fair	Fair	Fair
Skills of workforce	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Engineering design skills	Low	Low	Low	Low	Low	Low	Good
Bringing 'concept to reality'	Low	Fair	-N A-	Low	Good	Low	Low
Ability to develop long-term	Fair	Fair	-N A-	Fair	Good	Fair	Fair
Dependence upon proprietor	High	Medium	-N A-	High	High	High	High
Emphasis on training	Fair	Fair	Good	Fair	Fair	Fair	Fair
Focus on quality of product	Low	Low	Low	Low	Low	Low	Low
Marketing							
Knowledge of gasifier market	Low	Low	Low	Low	Low	Low	Low
Perceived marketing ability	Fair	Fair	-N A-	Fair	Good	Fair	Fair
Ability to sell concept	Fair	Fair	-N A-	Fair	Fair	Fair	Fair

Further, the team made an assessment of these shortlisted companies about their current strength and weakness and identified the gaps for further action.

3.3.2 Opportunities

- Many medium categories of private enterprises are interested in getting involved into gasifier manufacturing.
- Vocational/technical colleges have enough machinery to support private enterprises and train students in new processes.
- High investments from South African firms are being received in Uganda and there is mobility in terms of human resources between Uganda and South Africa. It makes it easy to close identified manpower gaps.
- The surveyed enterprises have basic equipment for gasifier fabrication.
- Over 50% interviewed manufacturers showed interest in getting involved in gasifier manufacturing.

3.3.3 Barriers

- Majority of the major raw materials used for fabrication process are imported into the country.
- Effects of inflation and exchange rate fluctuation could highly influence the cost of the final product.
- Most of the mid sized companies have limited design and production engineering capabilities.
- The companies do not engage in significant pro-active marketing activities.
- Use of jigs and fixtures to standardize and control is low.
- Skill and experience in fabrication of lightweight sheet metal and stainless steel production is too less.
- Lack of experience in corrosion and thermal design equipments.
- Limited capacity to make detailed production drawings.
- No focused quality control in the surveyed enterprises.
- No developed market channels for medium /small enterprises.
- Most of the enterprises are demand driven.
- Poor understanding of manufacturing of biomass gasifiers due to non-availability of technology in the region.

A-4 Market potential of biomass gasifier for heating applications in Uganda

This chapter elaborates on the future potential for biomass gasifier systems for heating applications in Uganda. Under this, potential sectors/ applications were identified for future demonstrations.

4.1 Market Potential of biomass gasifier for thermal applications in Uganda

The total woody biomass demand for household cooking and industrial application to meet the processes a heat requirement is estimated to be about 27.7 million tonnes[3] per year and is expected to grow in future. Out of the total demand of biomass, about 5.5 million tonnes is used in industries and for commercial purpose. Currently, biomass energy resources are utilized in low efficiency traditional systems and devices.

It is estimated that by adoption of modern biomass technologies, the country has potential to save about 14 million tonnes[4] of biomass annually, equivalent to 3.5 metric tonne oil equivalent (MTOE). More importantly, it will reduce the rate of deforestation to the tune of 1.75 million hectares[4] annually. On the other hand, industries and commercial enterprises use fossil fuel (furnace oil and kerosene) about 94000 m^3 per annum to process heat requirements. In a future scenario in which biomass replaces 100% of current petroleum fuels (e.g. furnace oil, Kerosene) in industries and commercial enterprises through biomass gasifier applications (forest residue); the additional annual biomass requirement is estimated to be around 0.38 million tonnes.

Against this backdrop, growing modern biomass technologies such as biomass gasification[4] has potential to penetrate in two segments:

- Institutional cooking applications
- Thermal applications in Micro, Small and Medium Enterprises (MSMEs).

4.1.1 Biomass gasifier for institutional kitchens

Commercial fuel wood consumption accounts for 14% of total biomass consumption, much of which is consumed in restaurants and bakeries. Majority of rural households, hospitals, schools, restaurants, hotels, police barracks and community kitchen in Uganda use fire wood for cooking. Very little data is available about this sector and the number of units operational in Uganda, but, the number of units using wood is in large numbers. The traditional stoves are made of a three stone stove where the cooking pot is aligned on the three stones leaving a certain space under the pot for firing with wood sticks. These traditional cooking stoves are highly inefficient and consume huge quantities of fire every day. At the household level, improved cook stoves, can be introduced which are highly efficient and environment friendly to meet cooking needs of individual households. However, for institutional or large-scale cooking the requirement of heating is too high, which cannot be met by these improved cook stoves. Hence, biomass gasifier based cooking systems have huge potential and can be

[3] The Development and Implementation of biomass gasification Pilot Activities – Final Report (submitted by TERI to MEMD in February 2009

[4] Gasifier basically converts solid biomass into more easy to handle and energy-efficiently usable cleaner combustible producer gas through series of thermo-chemical reactions under high temperature reduced (insufficient oxygen) atmosphere within the insulated gasifier reactor. Producer gas contains mainly hydrogen and carbon monoxide and has relatively low calorific value of the order of 1100-1200 kcal/Nm^3. Producer gas formed through gasification of biomass can in turn be used either to burn in burner to meet process heat demand or used in internal combustion engine to produce electricity.

replicated in this sector. These systems can be certainly replicated across the country in Uganda and this shall contribute to saving in biomass consumption in the commercial sector.

For large scale cooking, gasifiers can be used instead of conventional stoves, with gasifiers which have the following advantages:

- Reduction in firewood consumption by >50% compared the traditional stoves.
- Flexibility in using bio-mass as fuel (woody biomass and pellets from crop residues)
- Faster processing and less cooking time.
- Better control on burning.
- Smooth, trouble free operation.
- Improved working conditions.
- Reduced health hazards and CO_2 emission.

Under the energy audit study that was carried out by MEMD under the power sector development operation, a number of major institutions in the country were studied and recommended for installation of biomass gasifier for cooking system. A list of these institutions is given in the Table A-4.1.

Table A-4.1 Potential for biomass gasifier applications in Institutions for cooking

Category	Institution	Annual Wood saving potential (MT)
Hospital	Butabika Hospital, Kampala	135
Police	Kibuli police Training, Kampala	660
Police	Naguru Police Barracks, Kampala	432
School	TESO College	191
School	Wanyage Girls' Senior Secondary School	94
School	Nabumali High School	108
School	Gayaza Girls Secondary School, Gayaza	17,000 kWh
School	Nabisunsa Girls Secondary School, Kampala	27,000 kWh
School	Our Lady of Good Counsel Senior Secondary School	79
School	Lubiri Secondary School	108
School	Muntuyera High School	297
School	Ntare School	162
School	Mbarara High School	324
School	Mary Hill Girls School	43

Source: The energy audit study that has been carried out by MEMED under power sector development operation

4.1.2 Biomass gasifiers for thermal applications in industries

In recent years, the prices of energy, both thermal and electrical, have been increasing steadily. Biomass gasification technology offers the convenience of commercial fuels like LPG, diesel, and kerosene; but at much lower costs. Gasifier is a potentially viable system for very significant fuel saving.

The use of the gasifiers in heating applications such as tea drying, fish smoking, bakeries, tobacco curing, coffee roasting, restaurants, hotels and eating places and other sectors has a huge potential.

A partial list of industries who are potential users of biomass gasifier for thermal applications, the capacity of the system and their market size is given in Table A-4.2 below.

Table A-4.2 List of potential biomass gasifier industries/ institutions for thermal applications

S No.	*Application*	*Number of industries*	*Capacity of biomass gasifier Kg/h*	*Region*
1	Bakery	Not known	60-80	All over the country
2	Institutional cooking (school, hospitals and police barracks)	22000	100	Central and southern Uganda sothern and western Uganda
3	Coffee processing	20	60-80	Hoima, Kabarole, Kamwenge, Mubende and Mukono
4	Tea processing	37	100	Around the Lakes Victoria, Kyoga, Albert, Edward and George
5	Fish and meat processing	56	30-50	West Nile, Mid western Uganda and south western Uganda
6	Tobacco drying	Not known	80-100	Cross the country
7	Hotels/ Restaurants/ Eating Places	Not Known	10-50	Cross the country
8	Steel rolling mills	6	Not known	Jinja, eastern Uganda, western Uganda
9	Textile industries	Not known	Not estimated	Jinja
10	Plastic industries	Not known	Not estimated	Kampala and jinja
11	Soft drinks	3	Not estimated	Kampala, mbarara
12	Vegetable oil		Not estimated	Kampala Jinja and lira
13	Cement	2	Not estimated	Hima & Tororo
14	Breviaries	3	Not estimated	Kamapla & Jinja

The economics of a biomass gasifier system for typical tea drying unit in Uganda has been estimated and given in the Box A-4.1. Where the present study focuses on assessment of potential of biomass gasifier in heat applications however there is huge potential for decentralised electricity generation including rural electrification in long term.

Box A-4.1: Economics of biomass gasifier system for tea drying (Drier having 7.2 Tonnes/day output)

Conventional system

- Specific fuel wood consumption rate - 0.9 kg/kg of made tea
- Fuel wood costs - 44 USh/kg (approx 0.02 USD/kg)
- o Total fuel wood costs - 3740000USh/day (approx 1700 USD/day)

Gasifier system

- Capacity of gasifier - 360,000 kcal/h
- Wood consumption rate -120 kg/h
- Specific fuel wood consumption rate - 0.4 kg/kg of made tea
- Cost of processed wood - 60 USh/kg
- Potential saving - 114400 USh/day (approx 52 USD/day)
- Capital Investment - 35556400 USh (approx 16162 USD)
- Simple Pay back of Investment - 10 months

4.1.3 Biomass gasifier based power generation systems

In Uganda electricity access is still very low, standing at approximately 9% nationally and 3% in rural areas. In rural areas, where more than 85% of population lives, only about 1% of the households are connected to grid. Another 1% of the population provides itself with electricity using diesel and petrol gensets, car batteries and solar PV systems. Under the Integrated Rural Electrification Master Plan (IREMP) it was planned to increase the rural electrification rate to about 10% including about 100.000 off grids connections, phased over a ten year period.

In this context it is important to promote decentralized (distributed), off-grid electricity supply model for remote areas. Small-scale power generation, especially utilizing clean and local biomass energy sources, can play a key role in supporting expansion of electrification in Uganda.

In such a scenario, biomass gasifier technology for power generation has a huge potential to provide decentralised solutions for rural electrification. Apart from lighting, biomass gasifier can also provide the motive power for mechanical applications such as mills, presses, and water pumps in rural areas. Apart from rural needs, captive power generation using biomass gasifier based power systems can also meet the current demands in sectors including agro-processing, small scale industries, Information, Communication and Technology (ICT), rural growth Centre and Trading Centre. How ever the focus of this current study is on biomass gasifier for heat application because of its simplicity in construction and operation. How ever biomass gasifier for power generation are little complex when compared with heat applications shall be addressed during long term.

4.1.4 Potential benefits

The use and wide adaptation of biomass gasification technologies is expected to bring about the following socio-economic benefits to Uganda:

- Effect substantial reduction in the rate of deforestation due to local charcoal production and firewood use in an inefficient manner.
- Generates substantial savings in foreign exchange import costs of petroleum inputs for thermal/power generation.
- Enhance rapid expansion in the production of Biomass based energy generation and corresponding technology transfer and local energy production investment.
- Initiate a new culture of providing bank credits to local and community based investors.
- Affordable biomass energy production will create new employment opportunities, enhance establishments of medium size industrial amenities and Centres and hence contribute to modernization process of the static traditional communities.

A-5 Identification of policy interventions

In order to promote local production and market development of biomass gasifiers based heating applications in Uganda, a list of most important barriers under different category technical, financial, policy and institutional will have to be addressed. In this chapter policy initiative, including importance of facilitating South-South Cooperation that could contribute towards local development of biomass gasifier technology in the region has been suggested.

5.1 Policy formulation

A specific policy needs to be prepared through wide consultation with various groups of stakeholders, including different concerned ministries, industries associations and user groups, experts, NGOs, manufacturers, entrepreneurs, developers, financial institutions and district local agencies. MEMD may take lead in initiating the dialogue among the stakeholders and in policy formulation. A part of MEMD budget could be allocated for helping entrepreneurs not only in setting up the biomass gasifier business but also in meeting their requirements towards technology transfer/license, international cooperation, market development and capacity building in the initial period. The policy may encourage linkages between R&D institutes, plantation, biomass supply and processing, product development. Adequate budgetary support is also necessary to create higher market volumes that will in turn lead to lower costs of acquisition and maintenance of gasifier energy sources.

5.2 Human resources development

A significant thrust should be training at all levels towards capacity building and development of a human resource base. Vocational curricula for biomass gasifier energy may be developed starting from secondary school up to university level. Institutes for entrepreneurship development, polytechnics and engineering colleges may be strengthened to cater to the demand of skilled manpower in this sector. Human resources from Southern countries could be utilised in providing such vocational training. This has to be facilitated and be a part of South-South Cooperation measures for creating a platform towards technology transfer in intermediate technologies from South to countries of Africa.

5.3 South-South cooperation for technology transfer

A comparison of two technology applications viz. biomass gasifier and solar photovoltaic application reflects the fact that demand for PV applications in various sectors in countries like Ethiopia are benefitted through import of technological goods, equipments in the PV segment from countries like India. Also the scope of cooperation lies in the local module assembling from southern partners in the medium to long term.

But, in the short term, there is relatively a larger scope of intervention that can happen through South-South cooperation for building capacity in local production of technological components of biomass gasifier applications as very little has happened on this segment for biomass gasifier technology vis-a-vis solar photovoltaic technology applications.

One of the ways of promoting such South-South cooperation in these technologies could be through the South-South Technical Cooperation Centres of UNIDO that could work as leveraging centres to foster technology transfer and skill building programmes between the countries of Africa and other developing countries (see Box A-5.1).

Box A-5.1: South-South Technical Cooperation Centres

First of this kind of centre was launched in India in 2007. A major focus of this centre is renewable energy. This centre is working towards strengthening the existing partnerships between African, Asian, Caribbean and Latin American Countries through the International Centre for Advancement of Manufacturing Technology. UNIDO has also opened a South South Industrial Cooperation Centre in Beijing through an agreement that was signed between Government of China and UNIDO in 2007. The focus of the centre has been on renewable energy technologies like biomass gasifier, hydro and wind power. Funds have been directed from the government of India and China towards the operationalisation of these centres in areas of South-South Cooperation and technology transfer in renewable energy issues. Similar South-South Cooperation Centres are envisaged to be opened in Brazil, South Africa and Egypt.

The East African Community which is a regional intergovernmental organisation has to be brought in to create a regional programme on South-South Cooperation for renewable energy technology transfer to Uganda. Such programmes have to utilize the regional institutional structure like SADC, COMESA, to fasten the implementation of the programmes dealing with technology transfer. Technology transfer could be sought through the regional free trade agreements as a part of bilateral agreements between Uganda and Southern partners. Triangular cooperation between countries of South could also be sought for promoting South-South Cooperation in Uganda.

Such cooperation could follow a mechanism in which government of Japan provides funds to South-South cooperation unit of UNDP. These funds are being used for technology development and transfer by the South-South Cooperation unit of UNDP. South-South Cooperation units working under UN platform (like the one of UNIDO in India and China) could leverage, promote South-South cooperation partnerships through the options that have been designed under the Asia Africa Strategic Partnership plan of action. Funds for South-South Cooperation can be leveraged through special unit for South-South Cooperation. Triangular South-South cooperation could be thought of where the technology has to come from partners like India and China whereas the funds could come from the developed countries. The funding sources can be DANIDA, GTZ, SIDA who currently have a focus on development of biomass gasifier technology applications.

South-South financial funds can also be sourced from “Heavily Indebted Poor Countries Ministerial Network”[5]. South-South fund transfer for promoting technology transfer in countries like Uganda has the potential to create new forms of South-South partnerships. The critical question in this regard is to explore the possible potential regional origins for such South-South fund transfer. Some of the regional South-South monetary

[5] In September 1996, the IMF (Interim and Development Committee) and World Bank created a programme called initiative for the "Heavily Indebted Poor Countries" (HIPC Initiative) for giving assistance to countries for reducing external debt burden through earnings from exports, aid, and capital inflows. A ministerial network (Heavily Indebted Poor Countries Ministerial Network) comprising of ministers of the identified eligible countries who are eligible to receive fund assistance was formed. Fund assistance to the countries of this network is available based on the fact that there is a continuous effort to adjust macroeconomic imbalances, create social and structural reforms in the member countries of this network. Several countries of Africa who are part of South South Cooperation measures are eligible for seeking fund assistance from the HIPC initiative through the Ministerial network. This is a coordinated effort to channel funds to eligible countries who are important members of today’s South South Cooperation vision for bringing social reforms within the countries.

cooperation sources are: (a) ECOWAS, (b) the 22-member Arab Monetary Fund, c) the 7 member Asian Clearing Union (ACU); (d) the 5-member Latin American Reserve Fund. Most of these fund sources have regional focus of disbursement. Swedish funds for promoting energy policy in countries of Africa can be tapped for utilization in biomass gasifier technology in Uganda. Resources from African Capacity Building Foundation[6] have the potential for getting used for promoting South-South Cooperation in biomass gasifier and solar photovoltaic technology transfer in Uganda and Ethiopia. The money under this foundation comes from three sources viz. UNDP, African Development Bank, World Bank, African Governments and bilateral donors. EU funds for particular programmes in Africa oriented towards environment might be used as a fund source for biomass based gasifier technology transfer options in Africa.

Additionally, governments belonging to these groups can be approached to get some funds for technology transfer in Uganda. Uganda has already worked in joint commissions with other countries towards fostering South-South cooperation. One another source of fund can be under the UNDP Technonet Network Programme[7] which might be leveraged and used for creating technology transfer from India to African countries like Uganda.

Tokyo International Conference on African Development (TICAD), and UNDP Africa Bureau have merged together to create an initiative called “Africa-Asia SME Network (TECHNONET Africa)” that was established in South Africa in 2004. In this initiative, the funds have been coming under the framework of TICAD. The main function of this network is to share the Asian experiences in various technologies in small and medium enterprise (SME) development by forging a partnership with technonet Asia programme and also by learning from the experiences of Technonet Asia programme. Technonet Africa programme emphasises on how technology transfer could happen in small and medium enterprises in Africa following the technological knowledge pathway as observed in Asian experiences and Asia Technonet Programme. Technonet Africa has a focus on 7 African countries (including countries like Uganda, Ethiopia) that could be extended in the long run. One of the areas in this programme deals with technology transfer issues in food processing and metalworking segments of SMEs in the first phase. In this component biomass gasifier for heating applications could be thought of in the long run to create renewable energy technology transfer in food processing SME segments in countries like Uganda.

[6] African Capacity Building Foundation (ACBF) is an independent capacity building institution that is established by collaborative efforts of bilateral donors, AFDB (African Development Bank) , World Bank, UNDP, African governments. 41 African and non African countries and institutions are part of it. Japan has contributed financial resources to this foundation through the “Policy Human Resources Development” Trust Fund. Such resources could be used in creating South South Cooperation technology transfer in Uganda as Uganda is a part of ACBF.

[7]

A-6 Key findings and recommendations

Analysis in the previous chapters clearly demonstrates that the biomass gasifier offers high potential for growth in decentralized energy requirement of the Uganda. However, involvement of the private sector in local manufacturing, deployment and services of equipment holds the key to long term success of the technology. While in the present study the detailed assessment of the manufacturing capability of thermal gasifier was made, the technology has huge potential for electricity generation as well including rural electrification in long term basis. The gasifier technology for both thermal and electricity generation in the country is still at demonstration stage. If this technology can be demonstrated successfully and localized, then with proper policy push, biomass gasifier technology can make a significant contribution in effectively utilizing the country biomass resources in meeting the energy needs. Under the existing study the assessment of local manufacturing sector was carried out including their capability to take up the manufacturing of biomass gasifier systems.

Most of the industries indicated lack of skilled manpower in the country as a major barrier for expansion. It was clear from the survey that most of the high end fabrication units do not have immediate interest in diversifying into new products. However, mid sized companies had expressed interest in expanding into the gasifier market. The use of biomass gasifier for thermal application, as in the case of tea estate, demonstrates the saving of fuel wood by 50% and the payback of the system is within ten months.

A comparative analysis of locally produced biomass gasifier system with imported system has been made. For this purpose, the estimated cost of a 30 kg/h capacity biomass gasifier for cooking application has been worked out based on bill of materials, manpower cost and prevailing taxes and given in Table A-6.1. The estimated cost of the locally produced system was compared with biomass gasifier system of 30 kg/h capacity recently imported from India under the Energy for Rural Transformation (ERT) programme of MEMD, which has been set up at Kings College Budo for cooking applications.

The cost of the system imported for heating application (cooking needs) at Kings College Budo was approximately Ush 44 million (USD 22,000), which works out to be almost doubled than the expected cost of the locally produce system on account of higher costs towards taxes and duties, transportation costs, packing and forwarding, etc. Hence, there is a big scope for reducing the overall cost of the biomass gasifier system through local production.

Table A-6.1 Approximate cost estimate of biomass gasifier system for heat applications (30 kg/h capacity)

Particulars	**Amount in USh**	**Amount in USD**
Material cost	8034400	3652
Manpower cost	4888400	2222
Taxes	1335400	607
Profit	6461400	2937
Total	20719600	9418

The cost comparison made with the imported gasifier system shows there is big scope to reduce the overall price of the system, if produced locally. It is recommended that in the short term the biomass gasifier for thermal applications can be taken up with the involvement of the private sector. Once the gasifier technology is localized, then on medium term the technology can be extended for electricity generation by extended gas cooling and cleaning technology. Therefore as a next step, it is proposed that the knowledge transfer between technology supplier and key local manufacturers.

6.1 Creation of local manufacturers/entrepreneurs base and training

It is proposed that in the short term UNIDO may concentrate on facilitatiang at least 2 manufacturers of gasifiers and related equipment. Under the existing study a list of short-listed manufacturer has been provided. The selection of manufacturers would be crucial mainly on account of nature of the product. An eligibility criteria for selection of manufacturers can be evolved based on criteria such as overall capabilities of the manufacturer - the current level of operations, skills requirement, experience in similar business, long term business interests, marketing, after sales network (manufacturing defects warranty, etc.), financial soundness, credit worthiness, customer base, and willingness to take up quality control measures for gasifier section etc. Greater control is required in the initial stages by limiting the number of manufacturers producing gasifiers. UNIDO may engage Uganda Cleaner Production Centre for identification of the local manufacturers for this purpose. It is also proposed that UNIDO may facilitate the international exposure trip of key local manufacturers on design and manufacture of biomass gasification systems aspects. This would help in identify local manufacturers who can be involved in actual technology transfer.

Further, an integrated training program can be organized including all aspects of the technology such as design, manufacturing, installation, and servicing of gasifiers. This can be undertaken with the involvement of technology supplier and Kyambogo University, Uganda.

6.2 Pilot demonstrations and market development

Based on detailed assessment of the potential markets and their volumes and current industry structure and behaviour, a market penetration strategy may be developed for biomass gasifiers in consultation with different stakeholders. During initial phase of market development more emphasis may be given to applications where commercial fuels are to be replaced. It is important to test market the gasifier system in target industries not only to create awareness about the technology in the market place, but also to test the product and pricing strategies, financing mechanisms, supply chains, institutional arrangements, promotional strategies, etc., which offer the best potential for the subsequent market expansion. A few demonstration projects need to be formulated along with local manufacturer, the number and location of projects so chosen as to give maximum visibility to similar industry units.

The second phase will concentrate on issues like financing, local service delivery mechanisms, fuel supply linkages, quality control and certification. Extensive and continued discussions may be held with all stakeholders to formulate schemes for diffusion of gasifier systems in a near-commercial and sustainable manner.

6.3 Way forward

- The scenario that emerge from the assessment of the sheet metal fabrication industries in Uganda clearly indicate that the industries has sufficient machinery required for fabrication of biomass gasifier for heat applications. In order to promote the technology in a big way in the country for heat applications through setting up short and medium term goals such as:

- Technology transfer to the potential manufacturers in Uganda.
- Identification of potential industrial sectors clusters for technology promotion and adaptation.
- Strengthening the existing sheet metal fabrication sector in the areas of manufacture of biomass gasifier systems, quality control and operation maintenance of the same.
- Awareness creation among the stakeholder and capacity building of manufactures on biomass energy system.

The way forward suggested shall create new business opportunities for the local manufactures, gasifier users and clean energy promoters in Uganda.

- Awareness about the gasification technology among the various stakeholders such as manufacturers, end-users and the financial institutions is very low currently. There is a need to create awareness among the key stake holders in very short term (< 1 year), there is a need to bring in the technology experts to build capacity among the stakeholder through training workshops in Uganda and to create and build a team of people with expertise and knowledge about the technology.
- The local manufacturing sector needs to be facilitated through identification of suitable gasification technologies for heat application in private sector. The identified technology then needs to be taken for technology transfer through instruments such as south- south cooperation and others as explained in the report.
- Along with technology transfer there is a need for handholding support to the local manufacturers that needs to be provided by the concerned technology provider during the inception period i.e. to firm up the production cum marketing line and to establish it in the short to medium term (1 - 3 year time frame) see Table A-6.2.

Table A-6.2 Proposed activities during short, medium and long terms

Time line	Proposed activity
Short term	▪ The objective during this term is to build sufficient manufacturing capacity in Uganda and creating awareness among the stakeholder about the technology. Identifying manufactures and the end-users for biomass gasifier for heat applications and conducting training programmes addressing manufacturing, system sizing, financing and operational & maintenance aspects of the technology. ▪ Facilitation of technology transfer through south- south cooperation and other possible routes as indicated in the report. ▪ Identification pilot demonstration projects with in the country, showcasing the same and building a couple of case studies/ success stories and preparation of promotional material.
Medium term	▪ Identification of policy instruments and creating conducive policy environment for accelerated replication with in the country for heat application involving industries and private sector. ▪ For replicating the success stories within the east-African region, the initial approach shall be to export the system from Uganda by making Uganda as technology hub for the region.
Long term	▪ Up grading the local manufacturing capacities of the sheet metal industries for expanding into the gasifier based power generation market segment. This would enable to capture the rural electrification market which is yet to be tapped and also to meet the larger objective of the nation i.e. energising the rural holds. Building capacity with in the nation shall also cater the demand with in the East African region rural electrification market segment with in this region.

In order to create confidence among the stake holders about the technology there is a need to generate few local successes stories through pilot demonstration along with the involvement of private sector and building local case studies detailing the system performance, economics and pay back period etc:

- Replicating the success stories with the east-African region, the initial approach shall be to export the system from Uganda make Uganda as technology hub to this activity and simultaneously developing the local pool of manufacturers with in the respective countries in the region.
- To ensure quality of the gasifier systems manufactured by the local manufacturers conforming to the standards provided by the technology experts, there is a need to develop quality control mechanisms. The technology experts need to be appointed for training the local manufacturers on quality aspects related to gasification technology.
- Need for policy advocacy with local Government and facilitation to build conducive policy environment and enabling financial instruments such as provision of incentives for local manufacturing through tax holidays, tax credits, easy credit access, moratorium and other special incentives to promote the local manufacturing of cleaner technologies i.e. in this case biomass gasifier systems.
- Financial incentives in the form of easy credit access and soft loans may be provided through the existing REF mechanism for setting up local manufacturing. The REF is already facilitating credits for promoting dissemination of biomass gasifier for heat applications in the country.

SECTION **B:** Solar Photovoltaic applications

B-1 Energy situation and manufacturing sector in Ethoipia

1.1 Energy situation in Ethiopia

With only 6 % of households connected to the grid and 16% of the population having access to electricity from Ethiopian Electric Power Corporation (EEPCo), access to electricity in Ethiopia is one of the lowest by any standards (World Bank, 2007, IEA 2009). More importantly, despite the fact that over 80 %of Ethiopia's population live in rural areas with agriculture is the mainstay of the economy, electricity access to rural areas is only 2 % (IEA 2009). The energy demand forecast carried out with the LEAP model indicates that the demand, which was 700 PJ (194TWh) in 2000 is expected to grow to over 1900 PJ (527TWh) in 2030, a growth rate of 3.5 % per annum (EREDPC, 2007).

Biomass continues to be the main source of energy, accounting for almost 91% of the net energy supply (EEA, 2010). Among the end users, household sector accounts for 89% of the total energy consumption in the country. For lighting, kerosene is the major source of fuel among all rural households and businesses. Almost 71.1% of the total households use kerosene for lighting followed by firewood (15.7%) and electricity (12.9%). While the urban areas accounts for higher proportion (75.3%) of electricity use for lighting, the use of kerosene (80.1 %) and firewood (18.5%) are predominant in the rural areas (EEA, 2010).

Various surveys conducted in the past indicate that light is used for an hour in the morning and 3-4 hours at night in the rural households. In micro business, light is used for about 3 hours in the night. Paraffin lamp with simple wick and no cover is the most commonly used type of lighting device though the most preferred option is paraffin lamp with glass cover. Studies indicate that the average monthly running cost for a paraffin lantern is US$ 3.3 for households and US$ 2.62 for small business (IFC-The World Bank 2008). Figure B-1.1 provides the range of monthly expenditure for lighting in Ethiopia, estimated as part of a study conducted under the Ethiopian Energy Access Program (ESDA 2004). The complete requirement of kerosene is met by imports thereby draining on the foreign currency.

Dry cells are also another most important source of energy in rural areas. These are primarily used to power light-torches and radio/cassette players. It has been reported during survey of respondents that over 300 million dry cell batteries are consumed in the country annually. Another key feature of Ethiopia's electricity market reported during the survey is most of the diesel or kerosene gensets imported into the country are sold in the off grid market with most of them being in the lower capacity range.

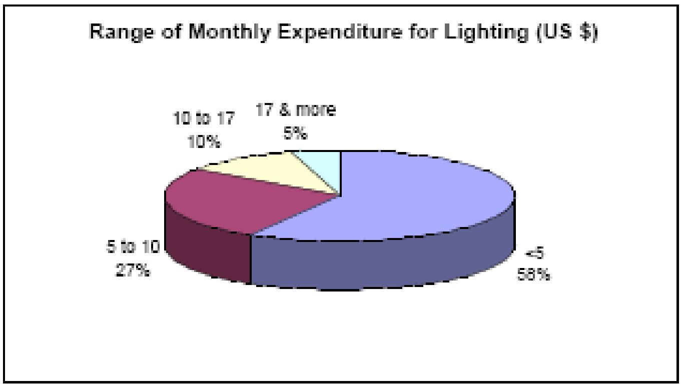

Figure B-1.1 Range of monthly expenditure by off grid consumers for lighting (Source: ESDA 2004)

The government under its Universal Electricity Access Program (UEAP), initiated in 2005, ambitiously planned to increase access to grid electricity to 50% by end of 2010 and connecting virtually all rural towns and villages to the grid with a 10-year horizon (World Bank, 2007). The UEAP also aims to raise the level of national per capita consumption of electricity to 128 kWh by the year 2015 from 32.9 kWh recorded in 2005-06 (World Bank, 2007).

With launch of UEAP, though the share of electricity has been increasing, it is still only 1.1% of the net energy supply. *Reports indicate that the electricity generation and consumption over the last four decades has grown on an average by 8.8% per year from 71 GWh to almost 2900 GWh in 2006* (EEA, 2010). Electricity consumption has been growing at an average annual growth rate of 4.25% over the period 1975 to 2006 with household sector registering a growth of 12.9 % during the same period. Considering EEPCos planned power generation projects are implemented as scheduled, electricity supply is expected to increase to 26 000 GWh in 2018 (Figure B-1.2). However, the demand is also forecast to rise in the range of 11 – 14 % per annum during this period. This is expected to lead to a power supply deficit scenario in the medium to long run in the country.

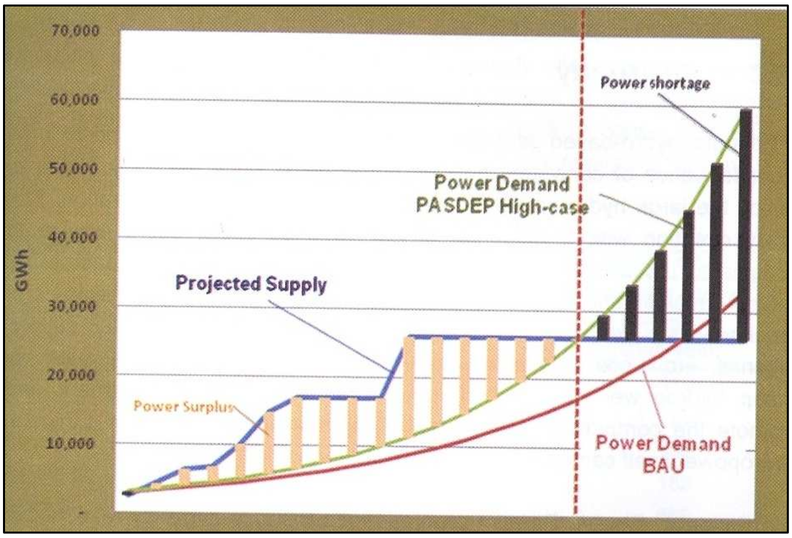

Figure B-1.2 Projected power supply and demand gaps
(Source: Ethiopian Economics Association, 2010)

This coupled with the absence of dedicated load and very low electricity consumption levels among rural consumers, economics of rural electrification through continuous grid extension does not favour rural consumers (dispersed demand and hence expensive to serve) in the short to medium term. On the other hand, the government's policy strongly emphasizes the need for poverty reduction through rural and agricultural development. The Government of Ethiopia under its overarching national economic policy of "Agricultural Development Led Industrialization" (ADLI) has embarked upon a series of social, economic and political measures aimed at reducing poverty and transforming rural economies through speedy and sustained economic growth. However, based on the historical record of electricity expansion in the country, access to electricity does not seem to be the reality of near future for majority of the rural population. As mentioned above, there are also further challenges in extending the grid network to the off-grid rural areas. Incorporating PV seems to be one of the most key strategies to enhance the electricity access in the rural areas.

1.2 Manufacturing sector in Ethiopia

Manufacturing industries in Ethiopia started with simple processing industries as early as 1920's, based on easily exploitable natural resources, such as textile, leather, food processing etc. The sector can still be considered in its infancy in many aspects of performance measures such as number of enterprises, investments, employment generated, and technology. The key reason for the very limited growth of the manufacturing sector is lack of appreciable investments in the sector. Further, the capacity of the sector for value addition i.e. the capacity to turn out new/additional products through the process of physical and chemical transformation of raw materials/inputs, is highly limited due to constraints in procuring advanced technologies and skills required for their use. The major industries which are doing value addition include sugar and sugar confectionary, articles of cement & concrete, malt & malt liquor, soft drinks & mineral water, and basic iron & steel. These industrial groups together contribute about 45% of the total value added (EEA 2010).

Off late over the last decade with government providing incentives, investment in manufacturing has also been gaining significance in the country (Box B-1.1).

Box B-1.1: Incentives for investment in manufacturing sector in Ethiopia

The Ethiopian Investment Agency is the government organ responsible for promoting, coordinating and facilitating foreign investment in the country. It is a one-stop-shop for all investors in Ethiopia. A foreign investor can undertake investment either as a sole proprietor, or jointly with domestic investors or with the Government. The minimum capital requirement for wholly owned foreign investment for any project in the area of engineering is US $ 50,000 in cash and/or in kind. In case of investment in partnership with domestic investors, the minimum capital requirement is US $ 25000. An exemption is provided to investor who exports at least 75% of the outputs and or reinvests his profit or dividend in the country. The Ethiopian government provides the incentives to investors in the manufacturing sector:

Facilitation and access to land for setting up the unit in industry zones

A tax holiday of 2-7 years for investments in manufacturing, agro processing, agriculture and ICT is granted to investors depending on the type and location of the industry, the number of employment opportunities created and the manufacturing plant's ability to use local raw materials and export potential of the unit.

Loss carry forward for half of the tax holiday period.

100% exemption from the payment of import customs duties and other taxes levied on imports is granted to import all investment capital goods, such as plant machinery and equipment, construction materials, as well as spare parts worth upto 15% of the value of the imported investment capital goods.

Exemption from the sales and excise taxes for all export commodities.

Source: Ethiopian Investment Agency, 2009

Critical industries for industrial development such as electrical and electronics industries do not exist in Ethiopia. However, this sector is emerging slowly and manufacturing of electrical and electronic goods averaged 3.6% of the total capital invested in the manufacturing sector during the period 2002-2009 (EEA, 2010). Though currently the type of investment is largely on assembly plants and simple manufacturing rather than production of advanced electrical or electronic components, the Government of Ethiopia is considering the sector especially the ICT (Information and Communication Technology) as one of the priority areas of investment in the country. Under ICT sector, production of semi conductors and other electronic equipment has been explicitly included for priority sector investment in the country.

B-2 Solar PV Technology

Solar Photovoltaic (PV) technology is primarily a solid-state semiconductor based technology, which converts a fraction of the incident solar radiation (photons) into DC (direct current) electricity. PV system can deliver electric energy to a specific appliance and/or to electric grid and because of their flexibility and modularity, the technology can be implemented on virtually any scale, size, connected to the electricity network or used as stand-alone or off grid systems, easily complementing other energy sources. They also offer several advantages viz. (i) complementary to other energy resources; both conventional and renewable, (ii) flexibility towards implementation and (iii) environmental advantages.

A basic PV system comprises PV modules and the BoS (balance of systems) that includes charge controllers, inverters, storage, luminaire, wiring and support structures. This chapter focuses on the solar PV technology, the components and applications of solar PV systems and global manufacturing status.

2.1 Solar Cell

Solar cells are devices that convert the solar energy into electricity, either directly via the PV effect or indirectly by first converting the solar energy to heat or chemical energy. The most common form of solar cells makes use of the photovoltaic effect and are generally called solar PV cells. Solar cells represent the fundamental power conversion unit of a PV system and are considered the heart of the PV systems. Its operation is based on the ability of semiconductors to convert sunlight directly into electricity by exploiting the PV effect. In the conversion process, the incident energy of light creates mobile charged particles in the semiconductor, which are then separated by the device structure and produce electricity.

Based on the different technologies and materials, the solar cell technology has been grouped in four different generations. The first generation solar cells are of large area, single-crystal, single layer p-n junction diode, capable to generate usable electricity from light sources with wavelengths of sunlight. These are typically made using diffusion process with silicon wafers. The silicon wafer-based solar cells are the dominant technology towards commercial production of solar cells accounting for more than 90% of the terrestrial solar cell market.

The second generation photovoltaic cells are based on the use of thin epitaxial deposits of semiconductors on lattice-matched wafers. There are currently a number of technologies / semiconductor materials under investigation or in mass production mainly amorphous silicon, polycrystalline silicon, micro-crystalline silicon, cadmium telluride, copper indium selenide or sulfide. One of the key advantages of thin-film technology theoretically results in reduced mass so it allows fitting panels on light or flexible materials, even on textiles. Thin film gained acceptance as a "mainstream" technology during 2006/2007, due partly to manufacturing maturity and lower production costs, and partly to its advantage in terms of silicon feedstock, and now commands 8-9% of the total production of cells.

The third-generation photovoltaic cells are proposed to be very different from the previous semiconductor devices as they do not rely on a traditional p-n junction to separate photo-generated charge carriers. For space applications quantum well devices (quantum dots, quantum ropes, etc.) and devices incorporating carbon nano tubes are being studied - with a potential up to 45% efficiency.

The fourth generation of photovoltaic cells are the hypothetical generation of solar cells; which may consist of composite photovoltaic technology, in which polymers with nano-particles can be mixed together to make a single multi-spectrum layer. The multi-spectrum layers can be stacked to make multi-spectrum solar cells more efficient and cheaper.

The first and second generation solar cells have been commercialised. The most common material for making solar cell is silicon. The lab scale efficiency of the mono crystalline silicon cell is 25% while that of the multi crystalline cell is 20.4% (Green et al, 2009). The efficiency of a solar cell depends on its ability to absorb solar radiation. Larger the fraction of solar radiation it absorbs, larger will be its efficiency and larger power it will generate. Taking this into account, multi-junction solar cells have been fabricated. Using these high efficiency solar cells and focusing solar light to 500X, high efficiency solar concentrator has been devised to give higher electrical power per solar cell. The last two generations of solar cells are still at research and developmental stage.

2.2 Classification of solar cell technologies

Depending upon the type of absorbing material used, manufacturing technique / process adopted, and type of junction formed etc., the solar cell technologies can be broadly classified as following:

- Wafer based crystalline silicon solar cells
- Thin-film solar cells, which includes, Copper Indium Gallium Diselenide (CIGS), Cadmium Telluride (CdTe), Amorphous Silicon (a-Si) etc.
- Emerging technologies such as thin-film silicon, dye sensitized solar cells; polymer organic solar cells etc.

Figure B-2.1 represents the classification of solar cell technologies along with their indicative market share.

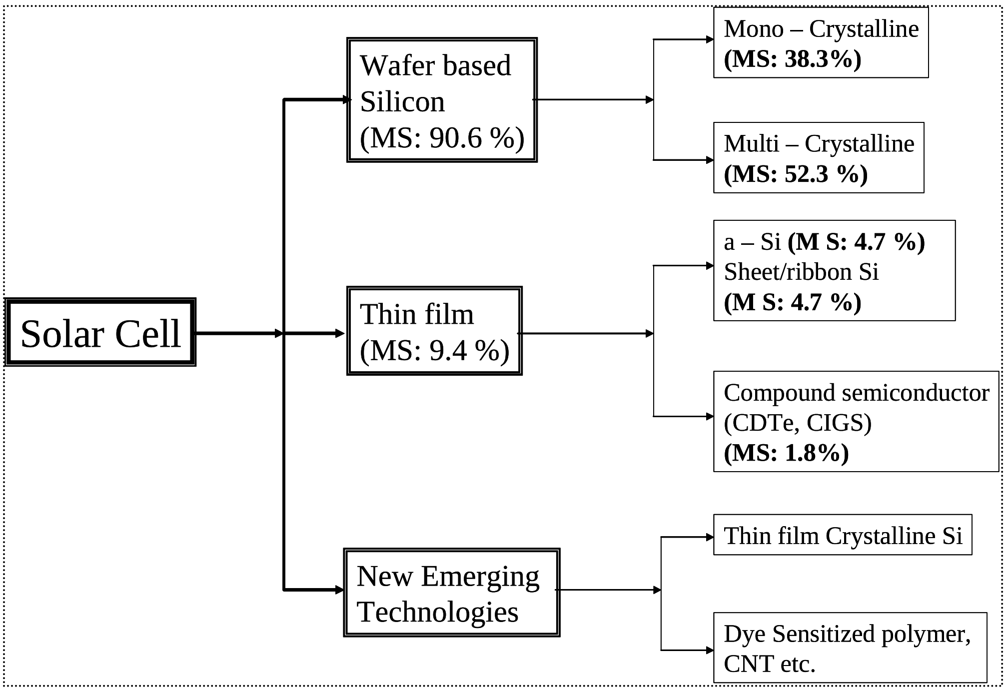

Figure B-2.1 Classification of various solar cell technologies
(Source: TERI)

2.2.1 Wafer-based crystalline silicon solar cell technology

The technology used to make most of the solar cells, borrows heavily from the microelectronics industry, is classified into two categories as:

- Single-/ Mono-crystalline silicon solar cell and
- Polycrystalline silicon solar cell

In wafer-based crystalline silicon solar cell technology, crystalline silicon modules are typically produced using the process shown in Figure B-2.2). The complete value chain for the most common c-Si solar PV module manufacturing is shown in Figure B-2.3

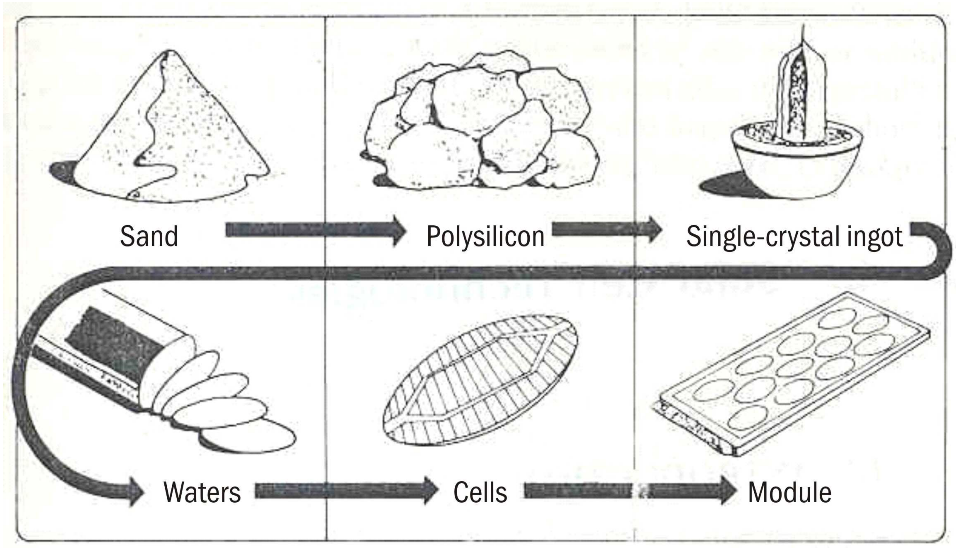

Figure B-2.2 Process involved in producing solar cell and module
(Source: TERI)

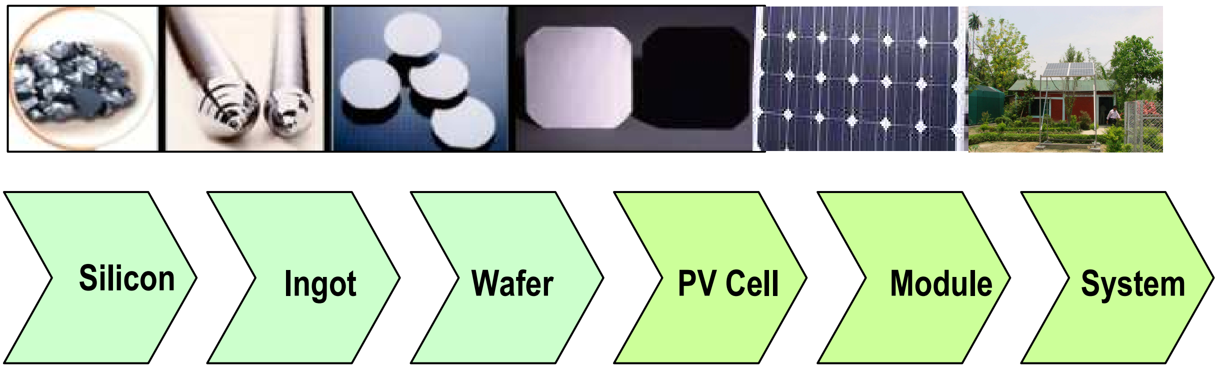

Figure B-2.3 Value chain in solar PV module production
(Source: TERI and Websol Energy)

2.2.1.1 Single/mono-crystalline silicon solar cell

This is the most established and efficient solar cell technologies till date, which have the module efficiency of 15 - 18% at commercial scale production (Figure B-2.3). These cells are manufactured from single silicon crystal, by process called Czochralski process. During the manufacturing, single crystal wafers are sliced (approximately 1/3 to 1/2 of a millimetre thick) from a large single crystal ingot which has been grown at around 1400°C.

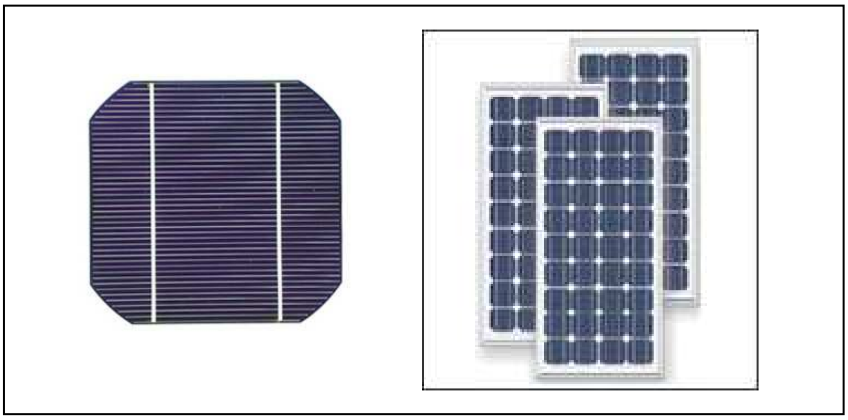

Figure B-2.3 Mono-crystalline silicon solar cell and module
(Source: Sun Tech Power)

2.2.1.2 Polycrystalline silicon solar cell (poly-Si or mc-Si)

Polycrystalline wafers are made by pouring molten silicon into a mould and allowing it to set. It is then sliced into wafers which can be much larger than the single crystal wafers (Figure B-2.4). The production of polycrystalline cells is more cost-efficient; however, they are not as efficient as single crystalline cells. These cells have module efficiency of around 12-14%.

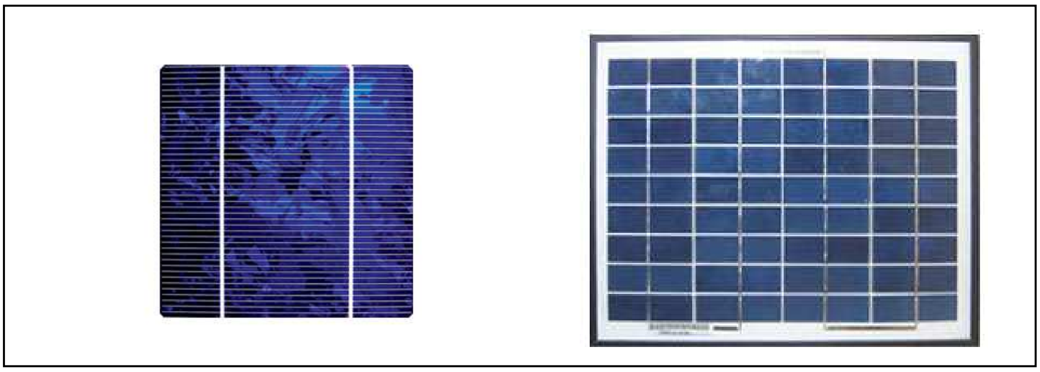

Figure B-2.4 Polycrystalline silicon solar cell and module
(Source: Alps Technology Inc)

2.2.2 Thin film solar cell technology

In this approach, thin layers of semiconductor material are deposited onto a supporting substrate, such as a large sheet of glass. Typically, less than a micron thickness of semiconductor material is required, 100-1000 times less than the thickness of silicon wafer (Figure B-2.5). Some of the thin film solar cells in use are as follows:

- a – Si (amorphous silicon)
- CdTe (Cadmium Telluride)
- CIS, CIGS (copper indium gallium di-selenide)
- Thin film crystalline silicon

Figure B-2.5 a-Si and CdTe thin film modules
(Source: Moser Baer India and First Solar Inc)

2.2.2.1 Amorphous silicon thin film solar cell

Amorphous Silicon (a-Si) modules are the first thin film solar module to be commercially produced. This can be fabricated at a lower deposition temperature hence permits the use of various low cost flexible substrates by easier processing technique. The major concern of a-Si solar cells is their low stabilized efficiency. The overall efficiency drops inevitably at module level and at present the efficiencies of commercial modules are in the range of 4-8% against the lab scale efficiency of 9.5% (Green et al, 2009).

2.2.2.2 Cadmium telluride thin film solar cell

Being a crystalline compound CdTe is a direct bandgap semiconductor, which is a strong solar cell material. It is usually sandwiched with cadmium sulfide to form a p-n junction PV solar cell. CdTe with laboratory efficiency as high as 16.7% (Green et al, 2009). have been developed at NREL (National Renewable Energy Laboratory). Multitudes of manufacturing techniques are main advantage of these solar cells which are suitable for large scale production. Limited availability of cadmium and pollution problem associated with Cadmium is main concerns with this technology.

2.2.2.3 Copper Indium Gallium Diselenide solar cells

This is a new semiconductor material comprising copper, indium, gallium and selenium in a specific order, which is used for solar cell manufacturing. It is one of the most promising thin film technologies due to their high-attained efficiency and low material costs. Amongst thin film solar cells, the advantage of CIGS solar cell is its extended operational lifetime without significant degradation. The inherent properties of CIGS also provide an opportunity for maximizing the efficiency.

2.2.3 Other new emerging technologies

Besides crystalline thin-film modules, Dye Sensitized Solar Cell (DSSC), organic polymer cells etc are emerging as new solar cell technologies. Although DSSC is still at the pilot production stage, it is becoming popular because of its potential for high-energy conversion efficiencies at very low cost. Besides DSSC solar cells, and other organic solar cells such as polymer organic solar cells have shown the promise of ease of manufacturing at low temperature and at low cost. However the efficiency as well as the long-term stability has to be improved further in order to compete it with conventional solar cells. Organic photovoltaic cells (OPVs) using carbon nano-tube are an attractive alternative to traditional silicon-based solar cells because they are inexpensive and can be manufactured more efficiently.

Table B-2.1 provide the comparative characteristics of crystalline silicon and thin-film PV technology.

Table B-2.1 Detailed Comparison between crystalline and thin-film technology

Parameter	Crystalline Silicon	Thin film
Types of Materials	Mono-crystalline Multi-crystalline	Amorphous silicon (a-Si) Cadmium telluride (CdTe) Copper indium (gallium) Diselenide (CIS or CIGS)
Material Requirement	Requires more material c-Si has been used as light-absorbing semiconductor in solar cells. To absorb sufficient amount of light, it requires several hundred micron thickness of material	Requires less material The selected materials are all strong light absorbers and only need to be about 1micron thick, so materials costs are significantly reduced
Manufacturing Process	Mono-crystalline is produced by slicing wafers (up to 150mm diameter and 350 microns thick) from a high-purity single crystal boule. Mono-crystalline silicon, made by sawing a cast block of silicon first into bars and then wafers.	Each of these three is amenable to large area deposition (on to substrates of about 1 meter dimensions) and hence high volume manufacturing. The thin film semiconductor layers are deposited on to either coated glass or stainless steel sheet.
Power	High power per given area	Low power per given area
Efficiency (Commercial)	11–18%	4.5–6.5%
Effect of Temperature	Effect is more on output power	Effect is less compared to crystalline silicon cells
Shade Tolerance	Low shade tolerant	More shade tolerant
Logistics	Fewer modules - lower shipping cost	More Modules - more shipping cost
Mounting structures Required	Fewer modules- less mounting structures per kWp	More modules- more mounting structures per kWp
Accessories	Requires less junction boxes	Requires more junction boxes
Inverters	High inverter flexibility	Limited inverter flexibility
Cost	High cost per watt	Low cost per watt
Output	Output depends on no. of cells in a 1 X 1 dimension module	Directly proportion on module dimension
Stabilization	Guaranteed power	It takes 5-6 months to reach a stabilized output
Commercialization	Most matured and commercially established	Very few suppliers

2.3 Components of Solar PV System

2.3.1 Solar Module

The power output of a single solar cell is too low to operate most of the electrical devices. Most single junction solar cells produce a voltage of about 0.5-0.6 V, regardless of the surface area of the cell. Therefore many cells are connected in series to increase the voltage. The interconnected solar cells are embedded in transparent Ethly – Vinyl – Acetate (EVA). The solar cells are also extremely fragile. Thus to protect the series connected solar cells, from damage, they are hermetically sealed between a top layer of glass or clear plastic, and a bottom layer of plastic or combination of plastic and metal. An outer frame is attached to increase the strength, and this whole package is called a solar PV module (Figure B-2.6). At the back of the module, a junction box is provided to extract electricity. Depending upon the load and battery requirements, the modules are connected in series and or parallel combinations and mounted on a metallic frame. Such aggregates of PV modules or panels form a solar PV array (Figure B-2.7).

The solar PV modules are rated in terms of *peak watt* (Wp). The insolation of a region indicates the total hours for which the rated peak watt from a module can be obtained. The performance parameters are expressed in terms of standard solar conditions: an ambient temperature of 25°C, and an insolation of 1000 Wh/m². The power output from a module depends upon the ambient temperature, solar insolation and the location of the site.

The solar array faces south (or north in the southern hemisphere) and is usually tilted at an angle to the horizontal approximately equal to the latitude of the site plus or minus 15° C depending on the application. This maximizes the solar energy collected during the year and reduces excess solar energy collected in the summer.

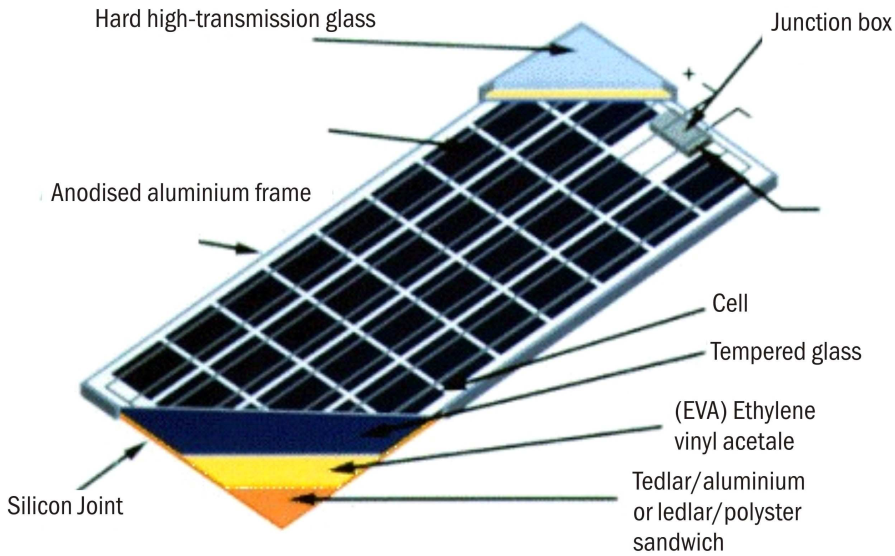

Figure B-2.6 View of a Solar Module

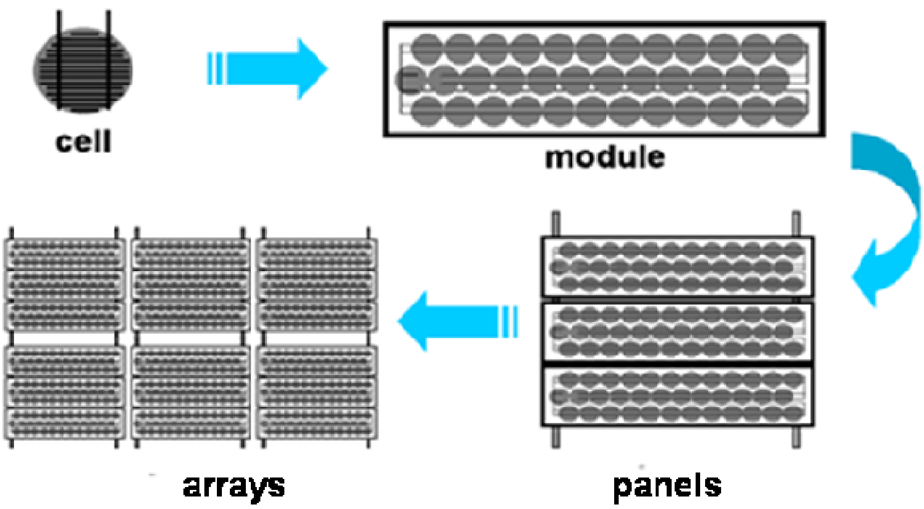

Figure B-2.7 View of a Solar module and array

2.3.2 Balance of Systems

All system components other than PV module are termed as the BoS (balance of systems). This includes storage (battery), charge controllers, inverters (for loads requiring alternating current), luminaire, wiring, conduits, metal structures for mounting the modules, and any additional components that are part of the PV system. The most critical components of the BoS are charge controllers and or inverters and the battery (which acts as the storage device in case of stand alone solar PV systems), which are described the following sections.

2.3.2.1 Battery

The battery stores electricity for use at night or for meeting loads during the day when the modules are not generating sufficient power to meet load requirements. A storage battery is an electrochemical cell which stores energy in chemical bonds. The cell is the basic electrochemical unit in a battery, consisting of a set of positive and negative plates divided by separators, immersed in electrolyte solution and enclosed in a case. In most cases a number of cells are packaged in a single container or sleeve, typically three or six 2V lead-acid cells to give a 6V or 12Vbattery. The rated capacity of a cell or battery (in Ah or mAh) is the amount of electricity that it can store (produce) when fully charged under specified conditions. Thus, the total energy of a battery is its capacity, multiplied by its voltage, resulting in a measurement of watt-hours. The three primary functions of a storage battery in a solar PV system are:

- Energy storage capacity and autonomy[8]: to store electrical energy when it is produced by the PV array and to supply energy to electrical loads as needed or on demand.
- Voltage and current stabilization: to supply power to electrical loads at stable voltages and currents, by suppressing or smoothing out transients that may occur in PV systems.
- Supply surge currents: to supply surge or high operating currents to electrical loads or appliances.

Usually, batteries can be divided into the following two types:

- Primary cells or dry batteries: The primary batteries can store and deliver electrical energy, but can not be recharged. Zinc –carbon and alkaline batteries are typical example of the primary cells. These are not used in PV systems as they cannot be recharged.
- Secondary cells or rechargeable batteries: A secondary battery can store and deliver electrical energy, but can also be recharged by passing a current through it in opposite direction to the discharge current. Common secondary batteries are lead-acid battery and nickel- cadmium batteries.

Solar PV systems require deep cycle rechargeable batteries to provide electricity over long periods. The user or the solar PV product manufacturers can select from a wide range of battery chemistry types which includes sealed lead acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), and Lithium Ion (Li-ion). Each battery type has different operation, performance and price characteristics that influence its suitability for a particular product line. For example, sealed lead acid batteries have a low price per unit of storage capacity, but their sensitivity to overcharging, deep discharge, or being left in a discharged state often leads to a relatively short operational life time. On the other hand, NiCd and NiMH batteries are less sensitive to overcharge and deep discharge, but are costlier per unit of

[8] Autonomy or the days of storage is the time during which battery storage capacity is sufficiently available to operate the electrical loads directly from the battery, without any energy input from the PV array

storage. However, in critical low temperature applications, NiCd cells are usually used. The critical performance parameters for PV batteries are storage capacity, charging and discharging efficiency, self discharge, and capability to operate in different state of charging modes and operation and maintenance procedures.

The following section describes the lead acid and NiCd batteries, as these batteries are usually used with solar PV systems.

Lead Acid batteries

There are many types of lead acid batteries, each having specific design and performance characteristics. The common types of lead acid batteries are:

- Automotive or SLI (Starting, lighting and ignition)
- Motive power or traction
- Stationary
- Lead antimony or lead calcium
- Sealed or valve-regulated

Automotive or SLI batteries: Automotive batteries are shallow-cycle batteries and are designed to discharge only about 20% of their capacity. The cell design in an automotive battery is optimised to deliver heavy currents, and it is therefore poorly suited to supplying smaller currents for many hours before being recharged. If drawn much below 20% capacity more than a few dozen times, the battery will get damaged. Automotive batteries are usually the cheapest batteries when compared by rated capacity, are widely available and repairable and easy for production. Although not recommended for use with solar PV systems, these batteries may provide upto a maximum of 2 years of useful service in small standalone where average *daily depth of discharge* is limited to10-20 % and *the maximum allowable depth of discharge* is limited to40-60 %.

Motive power or traction batteries: Motive power batteries are a type of lead acid batteries designed for deep discharge cycle service. They can tolerate discharge to as much as 80 per cent of their rated capacity, with a cycle life of from 1000 to 1500 deep cycles. They tend to lose water at a faster rate than other types of lead-acid battery, and therefore need frequent maintenance. They are commonly used for electric vehicles, golf carts, etc and are often known as traction batteries. Their self-discharge rate is also high. Though these batteries can be used in PV systems due to their deep cycle capability, long life and durability of design, they are relatively expensive and require lot of maintenance, increasing the recurring cost.

Stationary batteries: These batteries are often called stand-alone or standby batteries, and are commonly used in UPS systems when there is a grid failure. Stationary batteries may have characteristics similar to both SLI and motive power batteries, but are generally designed for occasional deep discharge, limited cycle service. In most applications they are kept fully charged by the mains supply and are ready to take the load whenever needed. They are extremely reliable, have a low self-discharge rate, and a long cycle life with shallow cycles, lasting up to ten years.

Lead-antimony solar batteries: These batteries are similar to stationary ones, but are designed for solar PV systems. The advantage of using lead–antimony alloys in the grids provides greater *mechanical strength* than pure lead grids and excellent *deep discharge* and *high discharge rate* performance. Most lead-antimony batteries are flooded, open vent types with removable caps to permit water additions. They are well suited to application in PV systems due to their deep cycle capability and ability to take abuse. Their self-discharge rate and distilled water consumption are both low. The cycle ranges from

1200 to 3000 depending on the discharge rates. These batteries are relatively expensive than automotive batteries and are usually available with PV systems suppliers.

Sealed or valve-regulated lead acid (VRLA) batteries: Common called VRLA batteries, these are captive electrolyte batteries, where the electrolyte is immobilized and the battery is sealed under normal conditions. Electrolyte can not be replenished in these battery designs and so they are intolerant of excessive overcharge. The hydrogen produced by these batteries is absorbed by chemicals inside them and they contain enough electrolytes for their entire life, so they are often called 'maintenance-free'. Sealed batteries have a short cycle life for deep cycles. They have a low rate of self-discharge and can support a full discharge, but must be recharged as soon as possible to prevent permanent damage. *The VRLA batteries are very popular with solar PV applications because they are spill proof and easily transported, any they require no water additions making them ideal for remote applications*. Two most common captive electrolyte batteries are the gelled electrolyte and the absorbed glass mat (AGM) designs. In the gelled lead acid battery, the electrolyte is 'gelled' by the addition of silicon dioxide to the electrolyte, which is then added to the battery in a warm liquid form and gels as it cools. In an AGM battery, the electrolyte is absorbed in glass mats which are sandwiched in layers between the plates.

Nickel-cadmium

The alternative to the lead-acid battery for solar PV system is the nickel-cadmium (NiCd) battery. Like lead-acid, NiCd batteries are available either vented or sealed. Vented ni-cad is designed for applications which require robust energy storage with long operating lifetimes and minimal maintenance. NiCd are less easily damaged by over-discharge or over-charging, and so simpler and cheaper charge control systems can be used to compensate for their extra unit costs. They are also more tolerant of extreme temperature variation than lead-acid batteries, and can operate at sub-zero temperatures.

However, one major disadvantage of this type of battery is that reversing the polarity when recharging a NiCd cell usually destroys it completely. This can sometimes happen, not because a cell was reversed by carelessness when wiring it up for recharging, but when one cell in a battery of NiCd cells is weaker than the rest: then the good cells can cause reverse charging of a weak one in certain circumstances, destroying the weak one completely. Another characteristic of NiCd batteries is a tendency to self-discharge rather more quickly than lead-acid cells and much more quickly than primary cells. NiCd primary cell substitutes therefore need regular recharging and are less useful for occasionally used loads than for regularly used ones.

Table B-2.2 describes the principal characteristics of different types of batteries.

Table B-2.2 Principal Characteristics of various batteries

Type	Depth of discharge %	Self discharge (capacity/month) %	No of cycles	Life (Years)	Advantages	Disadvantages
Flooded Lead Acid						
Automotive/SLI	20	30	300- 600	1-3	wide availability, low cost	Shallow cycle, low life, not suited for PV applications
Traction	80	5-7	1500	4-6	Deep cycle capability, long life, durable	High maintenance High cost
Stationary	50	3	3000	5-10	Deep cycle capability, long life, durable	Designed for occasional deep discharge
Lead-antimony	50	1-3	3000	5-10	Low cost, wide availability, good deep cycle and high	High water loss and high maintenance

					temperature performance	
Valve Regulated Lead Acid						
Gelled or AGM	20	2-6	400-1500	4-8	maintenance free, less susceptible to freezing, medium cost	Fair deep cycle performance, intolerant to overcharge & high temp
Ni – Cad						
Sealed	100	5-30	100 - 10000	3-5	Excellent deep cycle and low and high temperature performance. wide availability, maintenance free,	Only available in low capacities, high cost
Flooded	100	3-5	1000 - 2000	20	Excellent deep cycle and low and high temperature performance. tolerant to overcharge	Limited availability, high cost.

Source: Appropriate Technology magazine Volume 21/Number 2 September 1994 A T Brief No 9

2.3.2.2 Charge controller

Charge controller is a solid state electronic component, which controls the electricity generated by solar cells. It acts as a voltage regulator and is placed between the PV module and the battery. The primary function of a charge controller in a stand alone PV system is to regulate the rate and amount of electricity flow from the PV module to the battery and to protect the battery from overcharging or deep discharging. Absence of charge controllers in a PV system may result in shortened battery life and decreased load availability.

2.3.2.3 Alternating current system equipment Inverter

AC systems also require an inverter, which are electronic component and convert the DC (direct current) electricity produced by PV modules and stored in batteries into AC (alternating current) electricity. In a typical PV system, inverters are placed after the batteries (reasonably close to the batteries) and before the loads. Different types of inverters produce a different "quality" of electricity. For example, lights, televisions, and power tools can operate on lower quality electricity, but computers, laser printers, and other sophisticated electronic equipment require the highest-quality electricity. Inverters are sized depending on the load and the voltage (for example, whether the incoming DC voltage is 12, 24, 36, or 48 volts, the number of AC watts the load may require when they are operating normally and the amount of extra surge power the AC loads may need for short periods).

2.3.2.4 Other components

In addition to the above key components, other component in a solar PV system include a metallic mounting structure for installing PV modules on the roof top, pole or for ground installations. The physical mounting equipment comprises of metallic frames, nuts, bolts and clamps. All these materials should be corrosion resistant and are there made of galvanised iron. An acid proof and corrosion resistant vented metallic box or wooden box is provided to store the batteries. Apart from these, wiring and cabling are done to connect the load with the solar PV module, battery and charge controllers.

2.4 Solar PV applications

There is a large variety of solar PV products designed to meet the various needs. The applications of solar PV can be of the following modes (Figure 2.8):

Stand alone mode

Stand-alone systems are those with no connection to the utility grid. Stand alone mode consists of both decentralised/individual systems and centralised/community systems. For example a solar home systems (SHS) or power pack consists of solar PV modules, battery to store power and a charge controller/ inverter to allow appliances to be powered by solar electricity. Another common example is the solar lantern which is a single light point portable lighting system. Apart from the PV module, it consist of a lamp (LED or CFL), a battery (VRLA type), and electronic components, all placed in a casing, either made of metal, plastic, or fibre glass. Because of its portability, it finds both indoor and outdoor applications. Other common examples of individual systems are solar power packs (including roof top systems), solar pumps, street lights, etc. On the other hand, examples of centralized or community systems are village scale micro power plants, solar charging stations etc.

Grid connected mode

Grid connected system are those which are interconnected with the utility grid. In case of such systems, any electricity generated can be used locally and the surplus electricity is exported to the utility's grid. The utility-grid is used as a back-up supply in place of storage batteries. Common examples of grid connected PV systems are medium and large power plants, urban roof top systems, grid tail end voltage support power plants etc.

Some of the common applications of solar PV relevant to Ethiopian context are:

- Individual systems for home and small businesses: lights, TV, radio etc.
- Lighting for schools and hostels in remote areas.
- Refrigeration in rural health clinics.
- Battery charging stations in rural areas.
- Water pumping for small-scale irrigation, stock watering, and drinking water in rural areas.
- Household appliances such as ventilation fans, swamp coolers, televisions, blenders, stereos, and other appliances.
- Rural telecommunications by remote relay stations, emergency radios, and cellular telephones; and
- Utility grids that produce utility- or commercial-scale electricity.

Solar PV systems are most appropriate for the following advantages:

- Cost—when the cost is high for extending the utility power line or using another electricity-generating system in a remote location, a solar PV system is often the most cost-effective source of electricity.
- Reliability—PV modules have no moving parts and require little maintenance compared to other electricity-generating systems.
- Modularity—PV systems can be expanded to meet increased power requirements by adding more modules to an existing system.
- Environment—PV systems generate electricity without polluting the environment and without creating noise.
- Ability to combine systems—PV systems can be combined with other types of electric generators (wind, hydro, and diesel, for example) to charge batteries and provide power on demand.

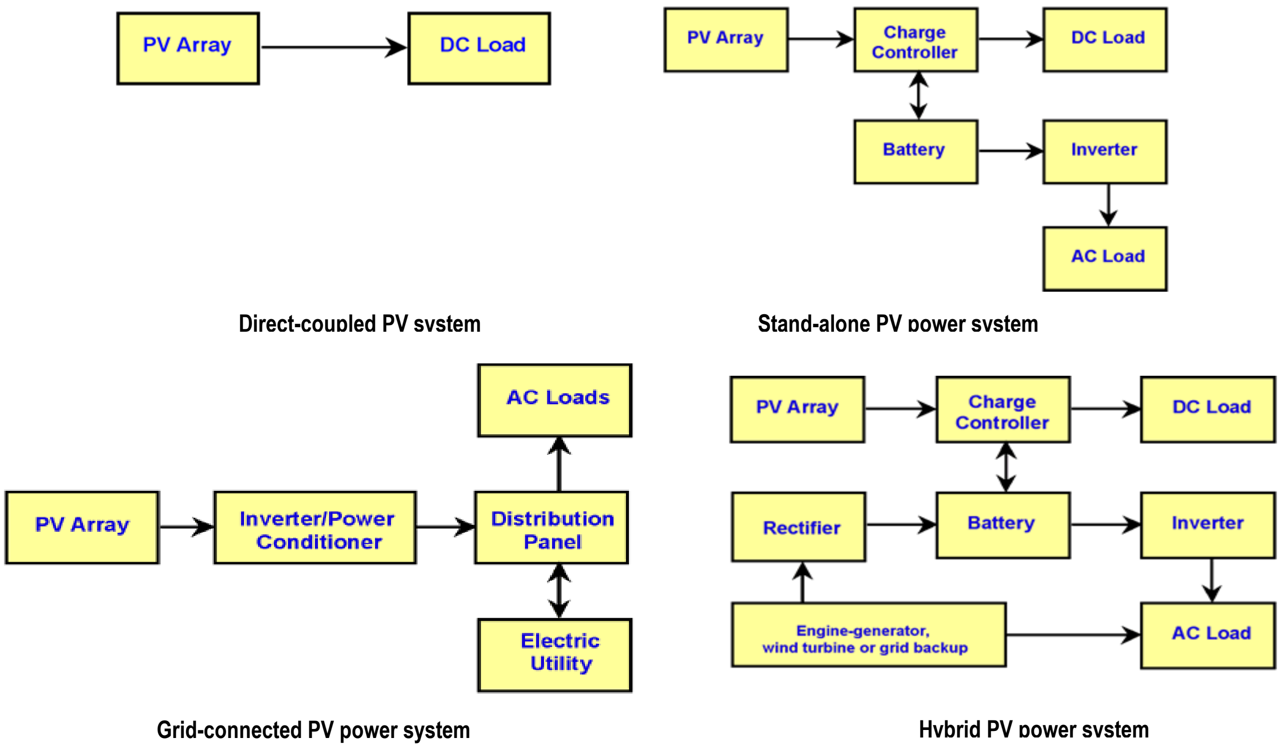

Figure B-2.8 Basic configuration of solar PV systems
(Source: TERI)

2.5 Manufacturers and global production

The total production of crystalline solar cells and thin film modules in 2009 has been estimated at 12.3 GWp (Photon International 2010). Table B-2.3 provide the market share of key solar PV cell manufacturers and Figure B-2.9 give the country wise solar cell production. This represented a 56% rise over the 7.9 GW production achieved in 2008 (Figure B-2.10). Multi crystalline solar cell remains the most popular product as the segment's production rose from 2 GWp to 5.8 GWp in 2009 (Photon International 2010). Globally, multi crystalline wafer account for nearly half of the solar cell market. As for mono crystalline cell, the total production was 4.2 MWp in 2009, accounting for 34% of the market share. In contrast, the share of thin film cells is only 9%. There are a large number of companies engaged in the manufacturing of PV cells with First Solar enjoying a clear leadership in the global PV market in 2009. The other major manufacturers include Q cells, Suntech Power, Sharp, JA Solar, Kyocera, Yingli Green Energy, Trina solar, Sun Power and Sanyo). Figure B-2.11 provides the manufacturers of products in the solar PV module production value chain.

Table B-2.3 Share of major producer of PV cells

Manufacturers	Technology	Production MW	Market share 2009 (%)
First Solar, USA	CDTe thin film	1100.0	8.9
Suntech Power, China	Mono Multi,	704.0	5.7
Sharp Corp, Japan	Mono Multi,	595.0	4.8
Q-Cells, Germany	Mono, multi	586.0	4.8
Yingli Green Energy, China	Mono, multi	525.3	4.3
JA Solar, China	Mono, multi	520.0	4.2
Kyocera Corp, Japan	Multi	400.0	3.3
Trina Solar, China	Mono, multi	399.0	3.2
SunPower, Philippines	Multi, mono	397.0	3.2
Gintech, Taiwan	Mono, multi	368.0	3.0
Rest of World	Mono Multi,	6728	54.6

Source: Photon International, 2010

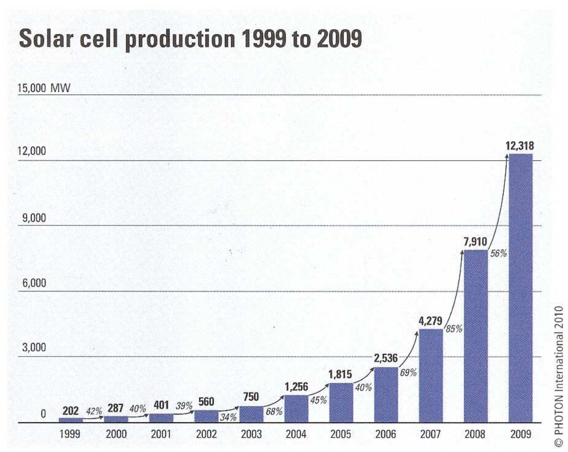

Figure B-2.9 Country share of solar cell production

(Source: Photon International 2010)

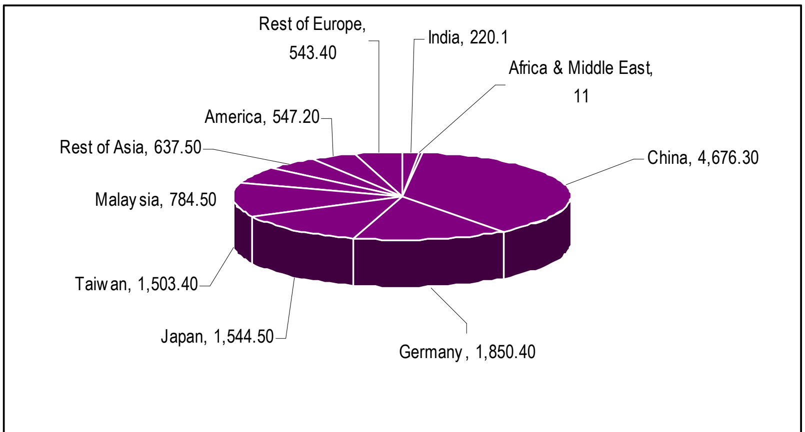

Figure B-2.10 Trend of solar cell production

(Source: Photon International 2010)

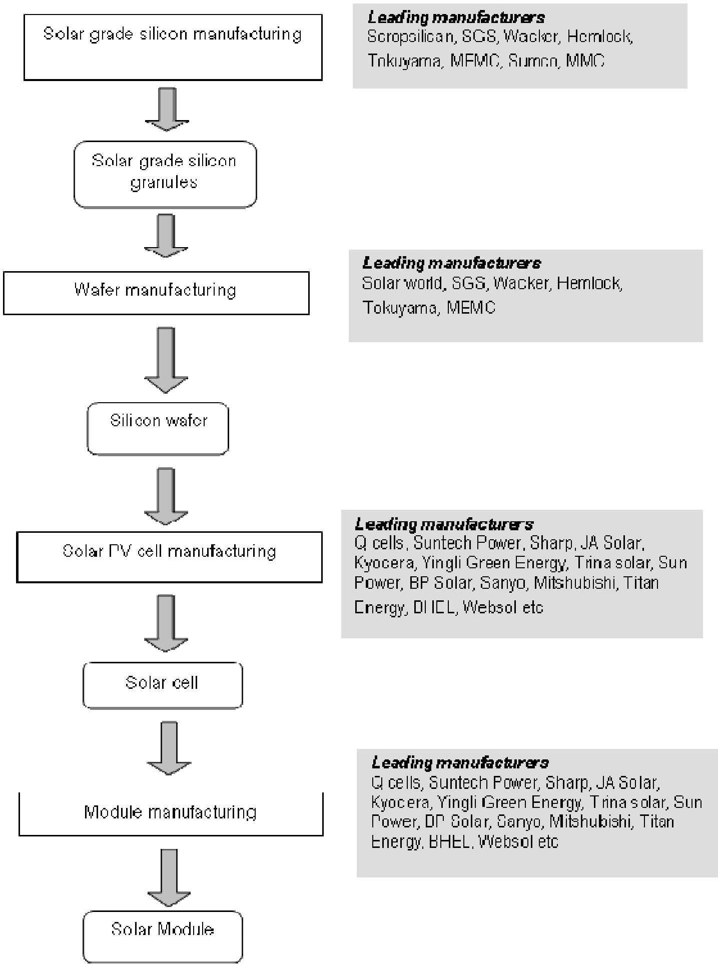

Figure B-2.11 Solar Module value chain manufacturer
(Source: TERI)

B-3 Solar PV in Ethiopia

3.1 Solar Resource Availability

As Ethiopia is located near the Equator, the solar resource potential is significant (Figure B-3.1). The yearly mean average daily radiation reaching the ground is 5.2 kWh/m²/day (Stutenbaumer et.al. 1999). There are seasonal variations (with a minimum of 4.55 kWh/m²/day in July to a maximum of 5.55 kWh/m²/day in February and March) as well as variation with physical locations (ranging from 4.25 kWh/m²/day for South west region to 6.25 kWh/m²/day in the north). Further, throughout Ethiopia the distribution of the global daily radiation around the yearly mean is quite narrow. The average for Ethiopia as a whole indicates that over 90 % of the radiation intensity is within 10 % of the mean value.

Figure B-3.1 Average annual insolation
(Source: Breyer et al, 2008)

3.2 Solar PV development in Ethiopia

In Ethiopia, humble beginning was made in the 1980's in the use of solar PV and other RETs (renewable energy technologies). The market still can be considered at its early developmental stage. Various groups including telecom, NGOs, research institutions, rural schools and clinics and to a lesser extent, private businesses and domestic consumers have been using PV systems for lighting, communication, entertainment and vaccine refrigeration for the past two decades. In the 1990s and early 2000, the market for solar PV was mainly a bidding based market for procurements of entire systems, especially SHS by NGOs. Most PV installations in the initial period were either project-based or donor-driven, which contributed to the underdevelopment of commercial market in Ethiopia.

The market started to develop from 2000 onwards with dissemination of solar equipments under the IGAD (Inter-Governmental Authority on Development) household energy project. The project actively promoted SHS among consumers and the business community. Currently, the total installed capacity of solar PV systems in the country is estimated at about 5.2 MW with almost 70% of the installation being in the telecom sector (EREDPC, 2010). Rest of the systems are in the off- grid sector, viz., household, small scale business and community systems. Though the commercial market started in early 2000, the annual sales growth was under 5% for almost a decade and a half. However, in the last few years there has been a steady growth averaging 15% to 20% year on year basis as reported by the PV dealers during the survey.

3.2.1 Key market segments

As reported earlier, the demand for solar PV systems in the household and small commercial sectors is growing significantly. With increase in the rural income, this demand is primarily coming from the need for lighting, powering TV sets and charging mobile phones. The growing institutional demand is primarily due to the catalytic role being played by the Rural Electrification Fund (REF) and support from various NGOs as part of their energy programmes (Box 3.1). The current annual demand is estimated to be more than 500 kWp (consisting of SHS, solar lanterns, solar charging stations for schools, health centres and telecom applications) with a large portion of the demand coming from government and NGOs (GTZ 2009). However, the survey indicates that currently about 50-100 kWp per year of PV systems is supplied to a market of off-grid NGOs, church organizations, donors and rural households. The solar PV market in Ethiopia can be segmented into following categories:

Box 3.1: Rural Electrification Fund

The Rural Electrification Fund was established through a proclamation (No. 317/2003) as a permanent financial source by the Government of Ethiopia. The fund was established with the following objectives:

1) To provide loan and technical services for Rural Electrification Projects carried out by private operators, cooperatives and local communities and more specifically for those projects operating on renewable energy sources; and

2) To encourage utilization of electricity for productive uses and on improving energy availability and quality of rural service sectors

The sources of the fund comprises of the budget allocated by the Government; loans and grants from other Governments; loans and grants form International Financial Institutions; grants from non-Governmental Organizations; and income from other different sources.

The establishment of Rural Electrification Fund is providing the required impetus to the growth of solar market in Ethiopia. REF currently has a goal of electrifying up to 150,000 households with solar PV systems for individual farmers in the rural places. It is also planning dissemination of 3 million solar lanterns within the next five years. Further, to provide a thrust to the market, REF has recently removed the limit of the introduction of solar PV systems in off-grid locations only. Solar PV system can now be disseminated in both off-grid and on-grid areas with REF support. In addition to the individual households, Government offices such as the Ministry of Education and Ministry of Health also benefit from the REF through the electrification of primary schools and health posts in rural areas.

Source: EREPDC 2010

3.2.1.1 Off-grid domestic and small scale business

In the off-grid sector, the solar PV systems mainly cater to households and small businesses. The major demand in this sector is for SHS for providing lighting, powering TV sets and music systems, and charging mobile phones, and for solar lanterns. Although in some cases, small scale businesses and shops etc do buy larger systems, the typical capacity for majority of the systems ranges from 20 Wp to 80 Wp. The total installed capacity for SHS in households and small commercial establishments is estimated to be over 1.2 MWp (GTZ 2009).The demand for SHS and solar lanterns is mainly from the cash crop growing areas as reported by the EREDPC (Ethiopian Rural Energy Development and Promotion Centre). One of the key driving forces for the PV market in this sector seems to be because of the financial support from REF, NGOs and international donors. For example, the REF has installed 1950 SHS (40-70 Wp system) and is in the process of installing another 7200 SHS. On the other hand, the Solar Energy Foundation, an international NGO has financed installation of 5200 SHS (20Wp/system) in different regions of the country and has also established a revolving fund to finance PV systems to rural households. It is reported that with growing telecommunication coverage, a micro system with a single light point and a mobile phone charger is also in high demand in rural areas. The growing demand from this market is due to the growing rural income over the past few years. Capacity building and awareness raising projects by GTZ and international NGOs such as Solar Energy Foundation and Plan International seems to have created the demand for SHS in rural households and businesses.

3.2.1.2 Off-Grid institutional systems

Off-grid institutional systems provide beneficial services to communities by increasing access to health, education and water or any other socially productive use in communities. The demand from health institutions and schools are entirely dependent on external support from government programs or NGO initiatives. The systems in this sector include SHS for institutional lighting, PV powered pumps, market lighting, vaccine refrigerators and ICT power (such as radio transmitter, computer kiosk etc). The total installed solar PV capacity in off grid institutional systems including health institutions, schools, and water supply systems is reported to be more than 500kWp (GTZ 2009). REF is supporting installation of systems and has tendered out 300 solar PV systems for the health clinics (360 Wp/system) and rural schools (200Wp/system) during 2009-10. Similarly, GTZ International is also implementing a project of electrification of schools and health centres (to keep fridges working to maintain vaccines) in the north eastern region of the country. Further, it is becoming a trend for the religious institutions to install solar PV systems to power their sound systems and musical instruments. An 80Wp system has been a typical size for rural religious institutions.

3.2.1.3 Telecom & signalling

The Ethiopian Telecommunication Corporation (ETC) has been implementing the Universal Connectivity Program since 2005 with the aim to cover all the villages in the country so that rural dwellers get telephone access. It is reported that almost 80% of the targeted 18000 villages have been covered and ETC will install additional 6000 to 8000 wireless telephones to cover all the villages (GTZ 2009). This would create a demand for over 200kWp systems for covering all the villages (GTZ 2009). Further, ETC also has plan to increase the number of wireless telephone units in each rural village to improve the connectivity. It is expected that installation of these telephone units would create an additional demand for about 1.8 MWp systems in the country (GTZ 2009). However, as the grid is being extended to rural areas, many of the new base transmission stations will be powered by grid electricity, which may create a saturation of solar PV application in the sector in the medium to long term.

Table B-3.1 Key market and potential for solar PV

Key market sector	Estimated installed capacity (MWp)	Current supply	Potential (Business as Usual)	Capacity range
Off-grid domestic and small scale business	> 1.2	50-100 kWp	200 kWp per annum	20 Wp to 80 Wp SHS and LED solar lanterns
Off-Grid institutional systems	> 0.5		200 kWp per annum	~ 360 Wp for health centres ~ 200Wp for school ~ 80 Wp for religious places
Telecom & signalling	~ 3.5	~ 150 kWp	2 MWp (cumulative)	50 Wp to 200 Wp for powering wireless telephones and BTS

3.2.2 Market potential

With rate of electrification extremely low in the rural areas, massive section of Ethiopian continues to remain without electricity access. The settlement pattern in rural Ethiopia is scattered making it extremely unattractive for extending grid based electrification. Given the distributed nature of solar PV, substantial portion of this market could be served using this technology. In terms of cumulative market potential, a recent study has estimated the solar off-grid market potential in Ethiopia at more than 52 MW (GTZ 2009). While another study has estimated the long term solar PV demand at 284 MW ranging from 2 Wp to 100 Wp systems with majority of the demand estimated is for 20 - 50 Wp systems (Breyer et al, 2008). As the demand is mainly from the off grid sector, solar PV systems will also have to be supplied with charge controllers and storage units (i.e. battery). Thus, there will be similar market potential for charge controllers and battery unit also in line with the demand for solar PV modules. During the survey, it was also found that there is also demand for individual solar lanterns (CFL and LED based) in the country.

Though the overall cumulative market potential is high, the current annual market (business as usual scenario) for solar PV products in the off grid domestic and institutional sector is about 400 kWp. This includes 200 kWp for off grid households and small business and the rest from the off-grid institutional sector (GTZ 2009). This is mainly due to supply constrained situation as the solar equipment dealers do not keep ready stock of the material because of price volatility of PV modules in the international market and difficulty in getting had currency for the imports. It is worth highlighting that many of the respondents shared during this survey that rural community member with adequate disposable income approach dealers for installation of Solar PV systems at their residences and farms. Coupled with the supply constrained situation, is the high price for the imported products. Both these factors are currently resulting in lower market volume.

Box 4.1: Solar PV demand in East Africa

A Lighting Africa study has estimated the fuel-based lighting market in sub Saharan Africa is at more than $17 billion per year (IFC-World Bank 2008). This market is still largely undefined, untapped, and unrealized. The current annual sale in the key East African countries viz. Kenya, Tanzania, Ethiopia, Uganda and Rawanda is about 2.5 – 3 MWp with a steady annual growth rate of 15-25% (Henkins 2009). The estimated potential of solar PV systems in these East African countries is more than 100 MWp in the long term with annual potential of 1.5 MWp

3.2.2 Key players in the PV market

There are about 15 solar equipment dealers and traders in the country, mostly concentrated in Addis Ababa. The key players are Lydetco, Beta Engineering, Direct Solar, Solar 23, SAT Solar, Ethio Resources Group and Ever Bright Solar etc. However, the solar business is a secondary business for most of these dealers or traders. As there are currently no manufacturing plants in the country for either the solar PV systems or components, the country imports all components and accessories required for its solar PV projects. Whereas the solar PV modules are usually imported from China, India and Germany, charge controllers are mostly procured from Germany. Most of the PV modules are imported from companies such as BP Solar, Kyocera, Sharp, Siemens and Suntechnics. In addition, unbranded products also find their way in the market. The batteries are procured from China and 'gelled' batteries from Germany. Being cheaper, auto batteries are also used with solar PV systems. Accessory items such as lamps, conduits and cables are procured locally. In some cases, conduits and cables are also imported along with other components mainly in case of bulk orders from government agencies or NGOs as locally manufactured cables are reported to be not of standard quality.

Further, the solar PV dealers mostly import the PV systems and components from the suppliers in small consignments. The main reason for importing in small quantities is the fear of tying up of capital on equipments in stocks due to volatility in international prices of solar components and limited finance available with the solar PV dealers. In most cases, it was found that solar PV constitutes a small share of the dealer's business. However, off late some local dealers (such as Solar 23, Solar Man etc) who have affiliation or linkages with European solar PV companies have set up their presence in the country. These dealers import solar equipments from their principal companies both for retail as well as supply to government or NGO projects.

While there are a few companies that import high quality branded solar PV components, in many cases companies also import low quality solar PV components. Even though there is high awareness and demand for the products, because of lack of any standardization, these low quality products find entry into the market. Further, during the survey, it was observed that it is also difficult to find original parts and products from the dealers. Even in cases where it is possible to get original parts there is no consistency as the dealers keep changing their suppliers and products offered. Another key issue is that of the use of automotive batteries with solar PV systems as the automotive batteries are available at lower price. However, the automotive batteries, being shallow-cycle batteries, are not suitable for use with solar PV systems, which require deep discharge batteries for ensuring longer battery life.

3.2.2.1 Solar PV consumers

The demand for solar products can be divided into rural-based consumers, the individual urban consumers and the institutions and organisational users. These rural consumers are mostly from areas having no or limited access to electricity. The key players among the institutional consumers are government agencies such as the ETC, Ministry of Mining and Energy, Ministry of Education, Ministry of Health, EREDPC and some regional governments. Some of the active NGOs working in the solar PV sector are Solar Energy Foundation, Ethiopian Solar Energy Society, Solar Man, and Plan International. The role of key players in the PV market value chain is provided in Table 3.2.

Table B-3.2 Role of key players in PV market segment

Market segment	PV manufacturer (International PV Co)	National (Importer/ distributor)	Regional (dealer/installer)	End user (Rural consumer)
Off grid household and small business	Provide equipment	Import and assemble Sales and marketing	Sales and marketing Install systems Spares/maintenance	Awareness Purchase of equipments Use of appliances
Institutional systems	Provide equipment Install and service	Import /Assemble Install and service	Post installation maintenance on behalf of its principal	Use of appliance Usually purchase is made by Government or donor NGOs
Telecommunication	Provide equipment Install and service	Possible role in assisting international company during installation and servicing	Little role	No role

3.2.3 Pricing of Solar PV systems

The prices of the solar PV systems in Ethiopian market are reported to be 2 to 3 times higher than the costs in Asian countries. In the context of the East African region, the prices are slightly higher than in Kenya, comparable to Uganda and Tanzania and lower than in Rwanda and Sudan. The prices in Kenya are low as compared to other East African countries mainly due to prevalent high sale volume coupled with no custom duty and VAT on the systems.

In Ethiopia, all solar PV equipments are flown in or imported in very small consignments and very few container purchases are made. Sales are characterized by high mark-up and low volume. The local dealers are neither able to invest in large stocks of equipment required to get the price breaks which could be passed on to the consumers, nor in the delivery chains required for efficiently delivery of the equipment. One of the reasons for not building up stock is because of declining trend in the international price of solar PV module and increasing dollar value against the ETB (Ethiopian Birr). While products from Germany and the United States are regarded as high quality products, they command a higher price. On the other hand products from Asia mainly India and China are imported at lower prices. Although products from China and India were perceived to be of lower quality as compared to European solar PV systems in the past, off late the comparable products from India and China have also started gaining larger market in Ethiopia.

The international cost of c-Si PV modules is about US$ 2 -2.5/Wp f.o.b (freight on board[9]) for large volume of orders. However, it was found during the survey that Ethiopian importers pay about 2.5 – 3.5/Wp (for c-Si) for procuring the modules because of the relatively low volume of orders. The dealers further shared that the freight, insurance, bank and clearing & forwarding charges altogether range between 5 % to 20% of the f.o.b prices and are dependent on origin and destination, and whether freight is by air or sea. Though it is prohibitively expensive to ship goods by air unless they have a very high value per unit weight, Ethiopia being landlocked country, most of the equipment comes by air. In

[9] FOB is used to show the price of the goods only and does not include the marine or air transport cost. FOB price is one of the elements to build the customs duty paying value, whereas the CIF (Cost, Insurance and Freight) value equals the FOB. value plus freight and insurance charges to the entry port of the importing country. It excludes transaction costs in the goods distribution chain between the port of entry and the inland destination (i.e. transport, clearing procedures, port charges, offloading and storage.

case of any shipment through sea, inland transport from Djibouti to Addis Ababa contributes 6-8% of the c.i.f price. Though currently there is no import/customs duty, there is still a surtax[10] (@ 10%) on the systems and an additional VAT (value added tax) of 15%. Retail margins vary from 15% to 40%, with large variations between different dealers, thereby contributing to the different pricing of the products for the end user. Thus, the final prices of the solar PV modules, when reaches the local market, sell for up to US$ 4.5 – US$ 7/Wp (ETB 60 –95/Wp).

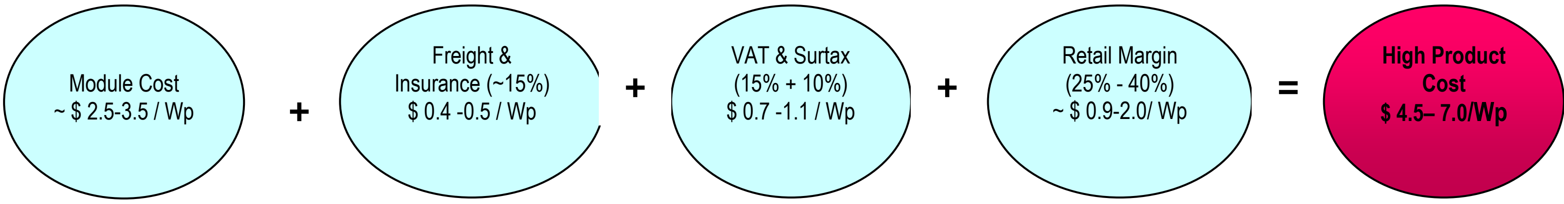

Figure 3.2 Prices of solar PV system

With regard to the cost of the complete systems with say 3-4 lamps, provision for powering TV and small appliance, the price is ETB 250-300 /Wp (US $ 18 -22/Wp). Individually, the price of a 50 Wp PV module ranges between ETB 3000 to ETB 4200 (US$ 225 to US$ 300) excluding the cost of installation and commissioning. The price of a charge controller ranges between ETB 400 to ETB 700 (US $ 30 to US $ 50) depending on the capacity (such as 6 amp, 8 amp etc). The cost of the solar lanterns ranges between ETB 500 to ETB 1500 (US$ 37 to US $ 110) depending on the model, illumination level, country of import and quality. Mostly gelled batteries are used in the country and are available at a cost of about ETB 2000 to ETB 4000 (US $ 150 to US $ 300) depending on the capacity whereas the cost of a 70 Ah the VRLA battery range between ETB 2500 to ETB 3000 (US $ 185 to US $ 225).

Table B-3.3 Price of typical solar PV components (as on March 2010)

Items	Price (in US $)
c-Si PV module (purchase cost in its country of origin)	US $ 2.5 – 3.5 / Wp
c-Si PV module (average retail cost in Addis Ababa considering different capacity of module incl smaller capacity size module)	US $ 4.5 – 7/Wp
Typical 50 Wp solar PV module in Addis Ababa	US $ 225 to US $ 300
Typical charge controller (depending on capacity)	US $ 30 to US $ 50
Solar lanterns depending on model and illumination	US $ 35 to US $ 110
Gelled battery (depending on capacity)	US $ 150 to US $ 300

Note: All prices mentioned here are approximations, indicated by the respondents during the survey

Further, in the absence of any officially-recognized standards or codes for solar PV appliances, the import of solar PV components by private companies is limited to small, non-regulated and with inconsistent quality. Consequently the companies are unable to develop a reliable partnership with overseas suppliers due to the insignificant amount and irregularity of orders. As a result the private companies order and buy the PV components from any supplier who can meet their needs at that instance. The situation is compounded because of the low technical know-how of the local end-user who may not be able to differentiate and specify the system and component types. Importing companies opt for the cheapest product

[10] Surtax (also called tax surcharge) is imposed in Ethiopia on certain finished goods items @ 10% from cumulative CIF value (Duty base value for surtax = CIF + customs duty + excise tax + VAT; Surtax = Duty base value X 10%)

they find and compromise on the quality of the components imported. Thus the private sector dealer is caught in the vicious circle of providing irregular and sub quality products and inability to increase sales volume. The dealers who provide quality solar PV components are also faced with the dilemma of low sales volume which forces them to charge exorbitant prices to compensate for the high transport cost and low sales volume. Many of the respondents expressed concern over the import of sub standard components at relatively cheaper price. Respondents said this low quality imported goods might affect the efficiency of the systems in the long run and thereby affect the market for solar photovoltaic products.

The government of Ethiopia has recently waived off the import/ custom duty in November 2009 on imported solar PV systems. Earlier, the duty was 20 % for solar PV modules and 30% for BoS. Although, this is a significant step towards bringing down the cost of the components to a reasonable level, the companies are still facing difficulty in the implementation of the incentive. Many of the organizations involved in the import of solar PV components shared during this survey that they face difficulty in benefiting from the duty waiver because of the lack of awareness on the technical specification of the products on the side of the customs officials. These companies are therefore frustrated by the amount of time required to clear the confusion and reap the benefits of the duty exemption. As the companies are pressed for time with their project timelines many opt to pay the duty and clear their consignments instead of filing the required complaints and finding solutions.

Moreover it was clear from our interaction with respondents that there is no specific government body responsible for the standardization of imported SPV components. All the above factors contribute towards making the solar PV systems very costly in the current situation. However, it is expected that with better awareness of the custom department officials, the waiver of custom duty will get properly implemented resulting in reduction of prices of an equivalent amount to the waiver.

B-4 Options for local manufacturing of PV components

The previous discussed the current situation of solar PV in Ethiopia and the overall market potential. This chapter provides the technical and financial assessment of solar PV module assembly and component manufacturing in the country and the industries' employment generation potential.

4.1 Technical Assessment

4.1.1 Assembly of solar PV components

Currently, assembly of components i.e procuring solar PV modules, battery and charge controller and assembling the complete SHS is being carried out in the country by few dealers and NGOs such as Solar 23 and Solar Energy Foundation. This assembling can further be strengthened through engaging and training the local solar PV dealers and TVGs (Technical Vocational Graduates) passing out from various institutes in Ethiopia. The trainings can be organised through South-South cooperation especially with India which witnessed phase wise growth of solar PV industry, from similar condition couple of decade back as in Ethiopia today, starting from system assembling to module assembly line to the current solar cell production. The assembly of the components will also not require high investment and thus can be considered in the short run.

4.1.2 Solar PV cells and modules

The solar cell manufacturing is gaining significant momentum on the back of surging demand of PV systems installations around the world. As mentioned in the previous sections, currently there are no manufacturing plants for solar PV modules or components in Ethiopia. However, with the growth in the demand for energy and the awareness on the technology, it was reported during the interaction with key actors that some companies from Germany (such as Blue Group Solar, Sun Transfer etc) are eyeing the Ethiopian market to establish manufacturing/assembly plants.

Manufacturing of solar PV components from raw materials (i.e. Si) is challenging given the high level of investment, technical know required and the current skill set available in the country. Thus, solar cell manufacturing is not feasible in the short to medium term and may be considered to be a long term goal for Ethiopia. However, solar module assembly line, which requires relatively less investment and does not involve very critical technical process, can be considered in the short to medium term for Ethiopia. Figure B-4.2 provides the complete steps of manufacturing PV module from PV cell.

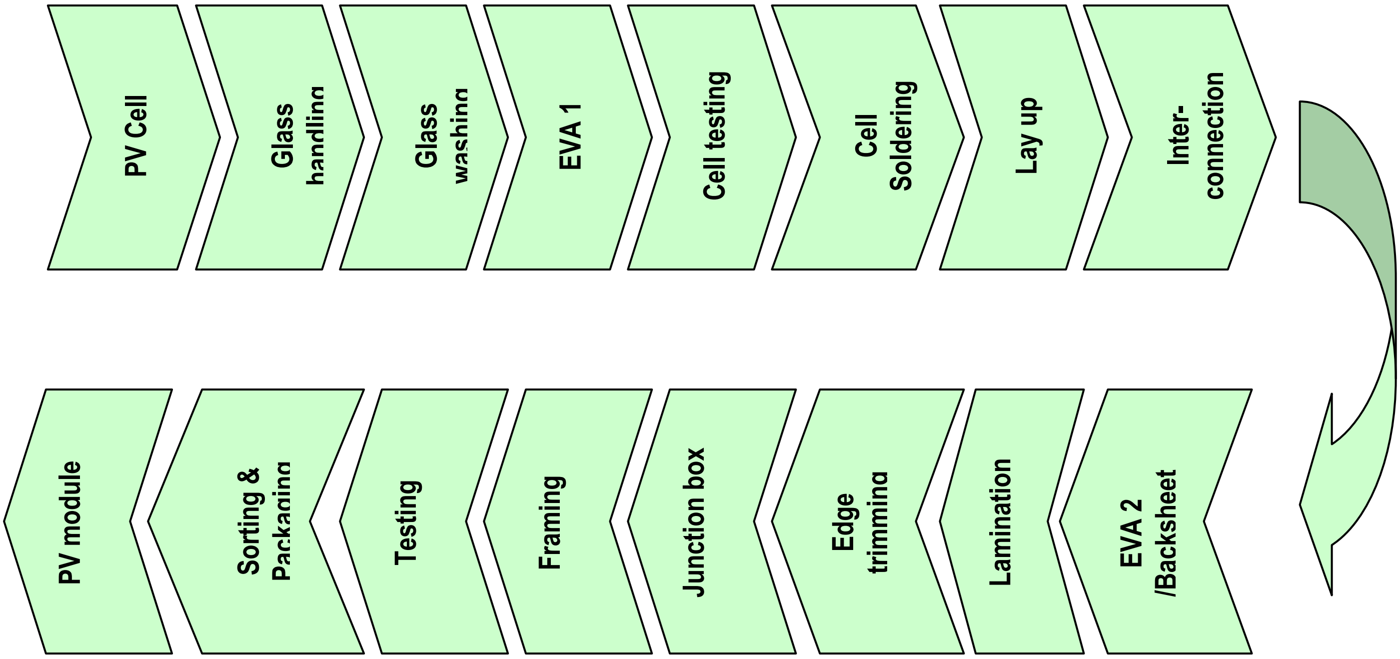

Figure B-4.2 Steps involved in solar PV module production from PV cells
(Source: TERI and 3S Industries AG)

All the steps shown in Figure B-4.2 could either be done in automated way or a mix of automated and semi automated way. Given the current skill set available in the country and investments required, while the main process such as cell soldering, lamination and simulator can be automated, the rest remain semi automated. However, it is to be ensured that the solar PV modules locally manufactured conform to the international standards such as IEC 61215: 1993 (Crystalline silicon terrestrial photovoltaic modules – Design qualification and type approval), IEC 61730-1:2004 (PV module safety qualification – Part 1: Requirements for construction), IEC 61730-2: 2004 (PV module safety qualification – Part1: requirements for construction and Part 2: Requirements for testing).

4.1.3 Battery

Another key component in the solar PV systems is the storage system i.e. battery. Battery manufacturing is an intensive, heavy industrial process involving the use of hazardous and toxic materials. Batteries production generally involves sequential and parallel processes to construct a complete battery unit. After production, initial charge and discharge cycles are conducted on batteries before they are shipped out.

The various type of battery generally used in a solar PV system are tubular plate deep discharge lead acid battery, sealed maintenance free VRLA battery and gelled battery. It was found during the survey that Ethiopia has a battery manufacturer (Awash Battery Plc) with production capacity of 20 000 unit/month. Currently the company is manufacturing 6000 auto batteries per month and is also planning to manufacture deep discharge batteries. During the survey, the company shared that it has already tied up with Indian experts and has also tested the prototype solar battery. This company can be involved and further trained to manufacture not only tubular lead acid batteries, but also the VRLA batteries, required for the solar lanterns and smaller capacity systems. For battery manufacturing, the local product has to manufactured conforming to international standards (such as IEC 61427 and IS 1651 /IS 13369 applicable for tubular lead acid batteries) to ensure strict quality control.

4.1.4 Charge Controller and Inverters

Currently, Ethiopia does not have the electronic industry and all electronic products are imported in the country. The charge controllers and inverters are electronic device and require highly skilled labour to fabricate. Further, charge controller technology constantly improves and so has to take care of the charging technology. In view of this, it is felt that the charge controller fabrication is not desirable in the short to medium run and the country can continue to import charge controller at competitive cost. However, with experience in solar module manufacturing and growing market demand, fabrication of charge controller and inverter can also be attempted in the country in joint venture with established international companies. The applicable standards for power conditioner/inverters are IEC 61683 for efficiency measurements and IEC 60068 -2 (6, 21, 27, 30, 75, 78) for environmental testing. In case of charge controllers, it should conform to IEC 62093 for design qualification and IEC 60068 for environmental testing. In addition, these systems should additionally conform to relevant national/international electrical safety standards.

4.1.5 Solar lanterns

Solar lantern is another product which has great demand in the rural Ethiopia and other East African countries. Initially, solar lanterns can be brought in CKD (completely knocked down) condition from India and or China, tested and assembled in the country. However, with experience of about 2-3 years in assembling of solar lanterns and gradual pickup of demand, these can also be manufactured in the country to cater to the local needs and also export of the product to neighbouring countries.

4.2. Financial assessment

4.2.1 Solar PV module

As mentioned in the previous section, Ethiopia offers the largest off grid solar PV market in East Africa with an overall market potential/projected demand estimated between 52 MWp to 284 MWp. On the other hand, the current total installed capacity of solar PV is around 5.2 Wp. This indicates a huge potential-demand gap that could possibly be met with local assembly of solar PV modules.

Based on the technical and market assessment and available capacity of module assembly line equipments, such as assembler, laminator and sun simulator, with the equipment manufacturers, a 5 MW solar PV module assembly line is proposed in Ethiopia in the short to medium term. The assembly line will have potential to produce 4MWp to 10 MWp annually depending on the number of production shifts (one, two or three shifts). Further, the module manufacturer will have more flexibility to procure the solar cell from vendors depending upon the efficiency of the cell and its price.

The cost of setting up a 5 MWp solar PV module production line is estimated to be about US $1.2 – 2.0 million depending on the scale of automation, location of plant, cost of land and shed. The annual turnover expected from sale of solar PV modules will be in the range of US$ 0.5 million to US $ 1 million depending on the quantum of module produced and sold from a 5 MWp assembly line.

The cost of production of solar PV module will depend on imported cost of solar cell, the energy cost for making the module from the cell, labour cost and other associated cost. As manufacturing sector is not well developed in the Ethiopia, almost all raw materials required for making the modules would have to be imported to the country. However, in this case while the solar cell can be airlifted because of its fragile nature, the rest of the raw materials can be shipped to the country.

The electricity cost in the country is cheaper as compared to many African or Asian countries and the labour cost is also comparable to the Asian economies. Since the country has cheap and renewable hydro energy in abundance, use of hydro energy for manufacturing solar PV modules cells can be an interesting application to produce 'green solar cells'. Installation of such a plant in the country can bring down the cost of solar PV module and systems substantially, making them cost effective. In view of this, it is expected that the cost of local production may be lower than those of imported ones.

4.2.2. Battery

The technical assessment indicates potential for a tubular plate lead acid battery manufacturing unit in Ethiopia with capacity to produce 5 – 10 thousand batteries per month (~ 40 -120 Ah capacity range) in the short term. The batteries thus produced will not only cater to the solar market, but can also meet the demand for inverter batteries and export market to neighbouring countries. In the medium to long term and with appropriate training and facilitation of technology transfer, the unit can start production of VRLA battery (4- 10 Ah) for the pico solar home systems (< 10 Wp with 2-3 LED light points) and solar lanterns. The approximate investment for the battery unit is estimated at around US $ 1.5 -2.0 million including land, housing and machinery as shared by the existing battery manufacturer during the survey.

Further, the interaction with the current battery manufacturer indicates that the cost of local production and import cost are almost same. However, there are other intangible advantages of local production as the warranty provided by the manufacturer can be serviced by local technicians. The consumer can get a replacement of the items or the item can be rectified in case of any manufacturing defect which otherwise is not possible in case of imports. In addition, these will also assist in creation of local jobs for servicing the equipments.

4.2.3 Solar lanterns

In case of a solar lantern assembly line, the investment is only for the testing equipments and is minimal. A semi automated solar lantern production line will be more practical for Ethiopian conditions as it will generate more jobs than an automated production line. A semi automated assembly line with capacity to roll out 25000 lanterns annually may require an investment of about US $ 15000 to US$20000, excluding the land and housing costs.

The cost estimates mentioned in the report are all indicative. A detailed study with exact costing, cost benefit analysis and potential profit/pay back period, for the local manufacturing of components identified in this report, is suggested to arrive at the final design and investment required for the manufacturing sector.

4.3 Employment generation

Considering the Ethiopian condition, the job creation due to growth of solar PV sector will mainly take place for module assembly line, installation, O&M and demounting sector in the PV value chain (Box 4.1). Various studies suggest that 25-30 direct jobs are created in the solar PV value chain for every MWp of PV installed (SEMI 2008). Further, 5-15 jobs are created as indirect employment for each person directly employed in producing solar PV systems. Thus, there is a potential to create 250-300 jobs for every MWp of installed capacity (say, 10 indirect jobs for every direct jobs) (SEMI 2008). With the potential to implement 50 MWp systems in the medium term, the direct and indirect job potential in the country is estimated at about 15000 jobs.

A 5 MW solar PV module assembly line can provide direct employment to 40 - 50 skilled persons depending on the automation level of the plant. A solar lantern production unit with annual capacity to produce about 25 000 lanterns will create job opportunities for about 80 to 100 persons.

Box 4.1 Type of job opportunities in the PV sector in Ethiopia

Jobs created in the production, installation and maintenance of photovoltaics

- Solar cell and module producers
- Photovoltaic equipment producers
- Balance of systems producers and suppliers
- System integrators and assemblers
- Suppliers and distributors
- Installers, service and repair technicians (Operations, maintenance and demounting)
- Site surveyors and assessors
- Managers and entrepreneurs
- Sales Representatives, marketers and estimators
- Project developers
- Designers
- Researchers and scientists
- Trainers and educators

To keep the pace, the number of local installers and technicians to provide installation and maintenance service will also increase. A hypothetical estimate by TERI indicate that for every 100 -150 SHS, solar power packs or lanterns being installed in the country in off grid areas, 1-2 person will be required to provide the installation and maintenance services. *With a potential to install 50 MWp of systems in the off grid areas, comprising of systems of 50 Wp (say), it is estimated that 10000 - 12000 green jobs will be created in the solar PV module and component manufacturing and maintenance sector over a period of 5 years*. This is in close range with the job creation potential in the solar PV sector estimated by SEMI study.

In addition, the local manufacturing of batteries is also expected to create jobs in manufacturing, marketing and recycling of the batteries. Most of these jobs will require skilled workers (Box 4.2). In addition, there will also be indirect job creation in packaging and transportation of the materials from the manufacturing facility to various rural areas in the country.

Box 4.2 Qualification profiles of the PV workforce
The qualifications required will differ depending on the stage of the value chain at which personnel to be employed in the PV sector will be active.

Solar cell and module production:
Skilled staff with background in chemistry, physics, electronics, electrical engineering or related academic studies with specialization and knowledge in the PV sector

PV system integrators
Engineers and technicians for the integration of systems In addition, highly skilled staff is required to provide services such as management, contracting, design and marketing issues.

Installation, commissioning, Operation and maintenance
Qualified technicians

Research and development
Scientists and engineers with a high level of specialization in photovoltaic

With the local production of s olar module and battery and assembling of lanterns and SHS, the market will also see accelerated growth from the current growth level and volume/sale is expected to increase substantially. The increase in volume is also expected to reduce the final cost of the product at the end user point. The local manufacturing can also help in not only cater to the local market but also export of solar PV systems to neighbouring countries such as Sudan, Uganda, Somalia, Djibouti etc.

B-5 Key findings and way forward

5.1 Key findings

Ethiopia, located near the Equator and with almost 80% of the total population of 80 million not covered by grid electricity, offers a good opportunity to the growth of solar PV. Because of the sheer size of the population with access to electricity, Ethiopia is the offers the largest off grid market potential in East Africa region. However, the market is still at an early developmental stage and is gradually transforming. The key findings from the study are:

- The rate of electrification in Ethiopia is extremely low with only 16 % of the total population having access to electricity. The electrification is almost non-existent in the rural areas. This leaves massive sections of off grid communities un-electrified by the grid. The settlement pattern in rural Ethiopia is very much scattered making it extremely unattractive for rural electrification options other than solar PV. Given the distributed nature of solar, a good portion of this market could be served using solar PV technology. Smaller products such small sized SHS or solar lanterns will considerably increase access.
- The estimated current installed capacity of solar PV in the country is about 5 MWp with almost 70 % of the installed capacity in the telecom sector. The rest of the systems are in the off grid domestic and small scale business sector and community systems. The major demand in the off grid domestic and community use is for SHS with typical system sizing ranging from 20 Wp to 80 Wp for providing lighting, powering TV sets and charging mobile phones.
- The growth in the PV sector, which averaged around 5 % during the last one and half decade, is now about 15-20% year on year basis and is expected to grow further because of the strong demand of PV products in the rural areas. Recently conducted studies by various organisations have estimated the solar off-grid market potential in Ethiopia between 52 MWp to 284 MWp for systems ranging from 2 Wp to 100 Wp systems.
- Currently, in absence of any local manufacturing in Ethiopia as well as in East Africa, the demand for solar PV systems comprising solar modules along with the balance of the systems is completely met by imports mainly from China, India and Germany by the local dealers of solar equipment. There are about 15 solar equipment dealers and traders, concentrated in the capital Addis Ababa. Of them only about 5-6 are active dealers and the rest are occasional players. However, the solar business is a secondary business for most of these dealers or traders. Further, these dealers seldom keep ready stock and imports as and when they receive firm orders from the government agencies or from the international NGOs working in Ethiopia.
- The prices of the solar PV systems in Ethiopian market are comparable to other East African countries. However, they are 2 to 3 times more than the costs in Asian countries and also vary widely from dealer to dealer. Although the purchasing cost of the solar modules in country of origin is

US$ 2.5-3.5 /Wp (for c-Si) when the products reach the local market they sell for up to ETB 70 – 100/Wp (US$ 5 -7/Wp). The high price of the systems is predominantly due to import of equipment by air, high tax and high retail margins by the dealers. However, with complete removal of import duty on solar energy systems with effect from November 2009, the prices have started coming down.

- Currently, there are also no regulations on the imports of solar photovoltaic systems and their components. Added to this is the lack of standardization of equipments which is resulting in import of sub standard products which are sold at prices similar to branded products. Without effective standardization and certification, the local manufacturing may find it difficult to compete with the poor quality products imported into the country at cheaper prices and sold at high margin.
- There is also an acute shortage of foreign currency, which has become a serious constraint for supply and stocking of solar PV equipment and accessories in adequate quantities.
- Another constraint is inexperienced players with capacity limitation both at the level of dealers/ companies and autonomous technicians. Major constraints at the level of PV dealers include: inadequate working capital, managerial skills, limited network both upstream and downstream and lack of specialization. Constraints on part of technicians include lack of organization, lack of technical skills for sizing and designing systems and inadequate skills for proper installation of systems.
- With the potential to implement 50 MWp systems in the medium term, the direct and indirect job potential in the country is estimated at about 10000 to 15000 jobs. However, currently there exist limited technical capacities and skills in the country for designing, sizing and installation of solar PV systems, especially the larger sized systems. Training will have to be imparted to the prospective technicians to build up the local capacity to manage the solar PV sector and sustain the growth.

5.2 Way forward

The opportunities that emerge from the assessment of the solar PV sector in Ethiopia pertain to setting up of the following in the short to medium term.

- Solar module assembly line
- Solar lanterns assembly line and
- Strengthening the existing battery manufacture unit for production of solar battery.

The way forward suggested for the growth of the solar PV sector and solar PV component manufacturing in Ethiopia are (Table B-5.1):

- Among the complete value chain of crystalline silicon based solar PV system, there is tremendous potential to start locally assembling of small capacity (5 -80 Wp) solar modules and solar lanterns and manufacturing of solar batteries in the short to medium term (1 - 3 year time frame). The local assembly may be established in joint venture with established players to ensure sustainable supply chain of raw materials and quality control of the product in line with the international standards. In very short term (< 1 year), the Ethiopian government can also facilitate assembly of solar lanterns through collaboration with South Asian lantern manufacturers.

- For ensuring quality control, the solar PV modules will have to be manufactured conforming to international standards as mentioned in section 4.1. UNIDO may engage the "Quality and Standards Authority of Ethiopia" and build their capacity in dealing with manufacturing of products conforming to international standards.
- The local assembling of solar modules and lanterns will also have to be accompanied by comprehensive capacity-building and handholding support to the local manufacturers till the raw material supply chain firm up and production cum marketing line get stabilised. The capacity building and handholding can be facilitated through South-South cooperation or bilateral cooperation say between India and Ethiopia.
- The comprehensive capacity-building also has to be supported by enabling financial environment by the Ethiopian Government such as provision of incentives for local manufacturing through, tax holidays, tax credits, easy credit access, moratorium and other special incentives) to help local market players engage in the new area (Box 5.1).
- Financial incentives in the form of easy credit access and soft loans may be provided through the existing REF mechanism for setting up local manufacturing. The REF is already facilitating credits for promoting dissemination of solar PV in the country.
- A project focussing on developing a detailed project report for solar PV module assembly line, solar lanterns and battery production may be taken up by UNIDO for design and selection of appropriate technology for Ethiopia and its cost benefit analysis.

Box 5.1 Special Incentive Package Scheme to promote PV manufacturing in India

The Government of India formalized its semiconductor policy in March 2007 with the launch of the Special Incentive Package Scheme (SIPS) to encourage investments for setting up Semiconductor Fabrication in India. Under this policy, the Government of India provides a package of incentives for setting up and operating semi-conductor fabrication and eco systems manufacturing units in the country. Solar cell and PV were explicitly included under the definition of 'eco system' units.

The incentives include 20 -25 % of the capital expenditure (for land, building, plant, machinery and technology) during the first 10 years through grants and interest subsidy or alternatively, through equity participation by the central government. In addition, the state government may also provide incentives, over and above this amount. The scheme has received enormous response with major existing PV players and large industrial groups submitting proposals. It is reported a total of 26 investment proposal amounting to INR 2,29,000 crore has been received by the government till 31 March 2010.

Source: Department of Information Technology, Government of India

Table B-5.1 Potential of local manufacturing of solar PV components

Time line	Proposed activity
Short term	Solar PV systems assembly involving solar integrators Tubular lead acid battery manufacturing involving the existing battery manufacturer in the country to meet the current demand and provide effective after sales service of the battery units Solar lanterns assembly from CKD (completely knocked down) condition procuring components from India and China to create and meet local demand Capacity building through South-South cooperation for creating a pool of solar technicians and solar integrators in the rural areas to support the solar PV installation
Medium term	A 5 MW solar module assembly line in joint venture with international PV manufacturer to meet the local and export demand Upgrading the solar lantern assembly to solar lantern manufacturing for catering the local and export demand Manufacturing of Sealed maintenance free VRLA battery for meeting the demand of the solar lantern manufacturers in the country
Long term	Increasing the capacity or the solar module assembly line or setting up of a second solar module assembly line depending on demand assessment Explore solar cell manufacturing unit in the country based on the demand and technical capacity of module manufacturer Explore fabrication of charge controllers and inverters based on the demand and technical capacity Strengthening the manufacturing of solar lanterns and other innovative solar products

In conclusion, it can be said that the key enablers for the PV market growth will be:
Easy availability of solar PV systems (through local manufacturing)
Enhanced business opportunity for local dealers (focussing on rural market)
Adequate training of service providers (through south-south cooperation) and
Prompt service (through creation of service network involving the trained persons).

Consolidated project summary

The summary of the findings of the pre-feasibility work that has been carried out in two technology components in Uganda and Ethiopia is given below:

Biomass gasifier for heating applications in Uganda

Existing industry/fabrication base

- The metal fabrication industry is very small, and caters to the local market demands.
- Currently there is no manufacturing base of gasifiers in Uganda.
- Mid sized companies dealing in fabrication of sheet metal products have shown interest to venture into gasifier market.
- Most of the high-end fabrication units cater to industrial and infrastructure related projects have no interest in diversifying into new products and market.
- The cost of the system imported for heating application (cooking needs) at Kings College Budo was approximately Ush 44 million (USD 22,000), which works out to be almost doubled than the expected cost of the locally produced system on account of higher costs towards taxes and duties, transportation costs, packing and forwarding, etc.
- The industries surveyed during the pre-feasibility study have essential equipment needed for fabrication of biomass gasifier systems. Hence there is opportunity for existing manufacturers to produce the same locally to cater to domestic requirements, provided they are facilitated with the appropriate gasification technology, through technology transfer, training, etc.
- Uganda can act as technology-hub for fabrication and export of gasifier systems within the East African region.

Barriers

- Low /or meagre understanding of biomass gasifier technology.
- Current product lines do not emphasize after sales service. There is a need to inculcate after sales service to promote biomass gasifier systems.
- Lack of knowledge in understanding the potential market.
- Most of the industries indicated lack of skilled manpower in the country as major barrier for expansion.
- These companies do not engage in significant pro-active marketing activities. Most of the products are repeat orders. The marketing capabilities of many companies are largely un-proven. Occasional participation in trade fairs are the only ways of expanding customer base.
- Limited capacity to make and interpret detailed engineering drawings.
- Quality control is minimal or non-existent in the surveyed enterprises.

Capacity building

- Vocational/technical colleges with adequate infrastructure are there to support the private enterprises and train students in any new processes but vocational curricula for biomass gasifier energy courses should be developed.
- Need for strengthening of vocational training institutes to produce trainers as well as manpower for the industry.
- Need to develop Local Service Delivery mechanism.
- Institutes for entrepreneurship development, polytechnics and engineering colleges should be strengthened to cater for the demand of skilled manpower in this sector. This may be done

through South-South Cooperation.
- It is suggested that more critical examination to estimate the exact cost of the gasifier system based on standard design and drawings is carried out with short listed manufacturers.

Policy initiatives
- Policy may encourage linkage between R&D institutes and manufacturer, energy plantation, biomass supply and processing, product development, deployment. Adequate budgetary support is also necessary to create higher market volumes that will in turn lead to lower costs of acquisition and maintenance of gasifier energy sources.
- Regional and sub-regional programmes of UN could be used as a window for promoting South-South Cooperation dealing with technology transfer to Uganda. Such programmes have to utilize the regional institutional structure like South African Development Community (SADC), Common Market for East and South Africa (COMESA) to accelerate the implementation of the programmes dealing with technology transfer.
- Triangular cooperation between countries of South could also be sought for promoting South-South Cooperation in Uganda.
- One source of fund can be from the United Nations Development Programme (UNDP) Technonet Programme, which might be leveraged and used for creating technology transfer from countries such as India to African countries like Uganda.
- Incentives scheme for seeding of the technology to create market demands.

Solar photovoltaic applications in Ethiopia
Existing Industry
- With a population of 80 million and almost 80% of the population not covered by grid electricity, Ethiopia provides a good potential for solar PV. The solar PV market currently is at an early stage of development with an estimated installed capacity of about 5 Mwp with majority of the systems in the telecom sector. The rest of the systems are in the of grid domestic sector, small scale business and off grid community systems, funded mostly by donor projects.
- Currently, the major demand in the off grid domestic and community use is for solar home systems with typical system sizing ranging from 20 Wp to 100 Wp systems catering to light, powering TV sets and charging mobile phones.
- The use of the solar energy systems is growing at 15% to 20% year to year and the market potential is estimated at more than 50 MW of solar home systems.
- The demand for solar systems comprising of solar modules along with the balance of the systems are completely met by imports mainly from China, India and Germany by the local dealers of solar equipments.

Potential local manufacturers
- There are about 15 solar equipment dealers and traders in the country. However, the solar business is a secondary business for most of these dealers or traders. Further, these dealers seldom keep ready stock and imports as and when they receive firm orders from the government agencies (such as energy, education, health) or from NGOs working in the country.

Policy initiatives
- The establishment of Rural Electrification Fund under the Ministry of Mines and Energy is also providing the required impetus to the growth of solar market.
- The cost of the equipments also varies widely from dealers to dealers and is dependent on the

import price. Off later, with complete removal of import duty on solar energy systems with effect from November 2009, the prices have come down by an average of 15-30% for different components.

Capacity building

- There exist limited technical capacities and skills in the country for designing, sizing and installation of solar PV systems, especially the larger sized systems.
- There is an existing auto battery manufacturer with a capacity to manufacture 20 000 batteries per month, who is also planning to manufacture deep discharge solar battery.

The above section highlights the summary of the specific findings of two technology components in Uganda and Ethiopia. Larger details on the individual study components are highlighted in Section **A** and Section **B** below.

Conclusion

Biomass gasifiers through involvement of private sector in local manufacturing, deployment of services, equipment can help in the penetration of this technology in Uganda. Gasifier technology for thermal and power applications is in a demonstration phase. Currently, metal fabrication industry is small and addresses the market demands. Development of skilled human resources is one of the necessities for technology development in Uganda. The imported biomass gasifier system costs double than the locally produced technologies. Local technology development can reduce this cost. But high end fabrication units are not interested in coming in biomass gasifier technology development. Whereas mid-sized companies can be involved in the short, medium term in the biomass gasifier technology development.

Most of the products are repeat orders. The marketing capabilities of many companies are largely un-proven and occasional participation in trade fairs are ways of expanding customer base. High investments from South African firms are being received in Uganda and there is mobility in terms of human resources between Uganda and South Africa. The barriers that exists in the country are - a) dependence on import of raw materials which gets effected due to inflation and exchange rate fluctuation, b) limited design and production engineering capabilities of mid sized companies, c) lack of marketing channels, d) lack of technical experience in corrosion and thermal design and e) lack of technological availability in the region.

However inspite of these barriers, in the short term, biomass gasifier technology for thermal applications needs to be developed with private sector involvement. With such diffusion in the short term, this technology can be extended for electricity generation with the help of extended gas cooling, cleaning technology. For development of local technology and entrepreneurs in biomass gasifier, Uganda Cleaner Production Centre has to be involved. Integrated training programme dealing with design, manufacturing, installation and servicing of gasifiers has to be developed.

In the first phase of technology development, diffusion, demonstration projects need to be established. For second phase, biomass gasifier technology development has to focus on local service delivery, financing, quality control, certification and fuel supply linkages. This has to happen through facilitating role of South-South cooperation policies and several financial incentives.

For the solar PV sector in Ethiopia, small sized SHS (solar home systems) and solar lanterns can enhance access to electricity. Solar PV based systems can meet demands for lighting, TV set powering and mobile phone charging. Demand for solar PV systems and modules are currently being met by imports from Germany, China and India. Most of the dealers are occasional players with 5 – 6 of them being active. The prices of the solar PV systems in Ethiopian market are comparable to other East African countries. However, they are 2 to 3 times more than the costs in Asian countries and also vary widely from dealer to dealer. However there are no regulations on the imports of solar photovoltaic systems and their components. Added to this is the lack of standardization of equipments which is resulting in import of sub standard products which are sold at prices similar to branded products. Without effective standardization and certification, the local manufacturing may find it difficult to compete with the poor quality products imported into the country at cheaper prices and sold at high margin.

There is an irregularity in the supply chain, one of the reasons behind which has been the hard currency problem. There is a need to establish regulation regarding the quality of the systems that are imported. Some of the other constraints that are faced by PV dealers are – a) inadequate working capital, managerial skills, b) lack of specialisation in the upstream and downstream, c) lack of technical skills for sizing and system design. With this premise, the solar PV sector can set up solar module, lantern assembly line in the short and medium term. Also existing battery manufacturing units can be strengthened. Local assembling of small capacity solar modules, lanterns can be started in the short to medium term. In a very short term, within the next 1 year, assembly of solar lanterns through the collaboration of manufacturers from South Asia can be established. Quality control of solar PV modules has to be strengthened in Ethiopia in the medium to long term. Local assembling of modules, lanterns has to be done through local capacity building, skill building facilitated through exchange of human resources from Southern partners. Incentives like tax holidays, credits, moratorium, easy loan provision, soft loans, and favourable interest rates can help in development of solar PV systems in Ethiopia in future.

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Annexure A-1

POTENTIAL OF
BIOMASS GASIFIERS MANUFACTURING IN UNGANDA
(Please use additional sheets wherever necessary)

1. Name and Address of unit

    1.1 Name ____

    1.2 Address ____

    1.3 ____

    1.4 Name of the Contact Person & Designation ______________________

    1.5 Telephone No. ____

    1.6 Telex No. ____

    1.7 Telegraphic Code ____

    1.8 Fax No. ____

2. Category of Applicant *(Pl. tick the appropriate)*

    Proprietorship/Individual ………..

    Regd. Partnership ………

    Private Ltd. Company ………

    Public Ltd. Company ………

    Central/State Govt. Undertaking ………

    Cooperative Society ………

    Registered Society/NGO/ __________ ………

    Other __________________________ ………

3. Date and Year of incorporation:……….

4. Date and Year of Commencement of Business ……….

5. Brief write-up on the present activities of the company:

6. Brief description of the nature of business of the company:

   Precision, general and industrial fabrication, Drafting services using AutoCAD, Sheet metal works.

7. Areas of Specialisation (SHEET METAL FABRICATION, PRESSURE VESSELS etc.)

8. Products and Services offered (Please enclose brochures, if any):

   (Enclosed as Annexure…….)

9. Organisation Chart of the applicant, indicating number of persons employed at various levels such as managerial, technical, skilled workers and unskilled workers of the applicant

   (Enclosed as Annexure……)

10. Please provide details of any technical, commercial, financial, marketing and other collaborations/agreements made by the applicant till date or proposed to be made in the current financial year?

11. Please provide a complete list of projects executed by you in the last five years as per Form –1

12. Please provide the list of projects awarded during last three years as per Form – 2 and the volume of total work on hand.

13. Please provide the list of projects awarded and completed satisfactorily in the last five years for the equipment's/works which are similar to the manufacture, marketing, installation and servicing of Biomass Gasifier systems.

    Manufacture or Fabrication or Assembly of the similar systems.
    Installation of the similar systems
    Installation and commissioning of the similar systems
    Operation and maintenance of the similar systems

Applicant's Sales Performance in case of the similar systems or applications

Industry	*Applications*	*System*	*Total volume of business executed*				*Total volume of Business Executed*			
			06-07	*07-08*	*08-09*	*09-10*	*06-07*	*07-08*	*08-09*	*09-10*
			Number				*in USD/ Shrillings*			

Please provide information on your manufacturing capabilities, plant facilities, machines, infrastructure, etc.?

14. Plant facilities: Please provide a detailed list of equipment and machinery available with you.
(Enclosed as Annexure ………)

15. Plant location

		Sq. meter	Remarks
a)	Space available for manufacture	……………………..	…………….
b)	Space available for storage	…………………….	…………….
c)	Space available for inspection items offered	…………………….	……………..
d)	Space available for storage of items	…………………..	…………….

e) Are power and fuel supply adequate to meet production requirements? ………………………………………….Yes/No

f) Are adequate transportation facilities available? …………………………………..Yes/No

k) Are adequate material handling equipment available? …………………………...Yes/No

16. Details of testing facilities:

a) List testing equipment available

b) Give details of tests, which can be carried out on items offered.

c) Details of the testing organization available.

17. Personnel/Organization:

18. Give organisation chart for following, indicating clearly the number of employees at various levels:

a) Production

b) Marketing

c) Installation and commissioning

d) Service

e) Spare parts

f) Administrative

g) Others …………

Service centres in various locations

Location & Address	Location	Phone No.	Contact person

19. Describe Quality Control Organization, and give the Organization Chart.

(a) Are goods offered subject to batch test, random sampling, or full 100% test for quality?

(b) Are tests carried out by factory employees or by a separate testing agency?

(Enclosed as Annexure………)

(c) Are any checks made by any independent Quality Control Organization and enclose the certificates issued?

H List of components to be subcontracted

____

____

20. Details of organization at each of the service centres:

a) No. of skilled employees ________________
b) No. of unskilled employees ________________
c) No. of Engineering employees ________________
d) No. of administrative employees ________________
e) List of special repair/workshop facility available
f) The storage space available for spare parts Sq. m.________________

g) Value of minimum stock of spares

Available at all the centres ______________________

h) List of model/types by number of equipment

Serviced by the centre in last 2 years ______________________

Are you willing to undertake manufacturing and market development for biomass gasifier?

Any other information that you wish to provide?

Date: Signature and seal of the

Location: **Authorised Signatory of the Organization**

(Please attach copies of certificates from your client)

FORM – 1

FORM FOR LIST OF PROJECTS AWARDED DURING THE LAST 2 YEARS

Name of the Applicant: ………………………………………………………………………………………………

S.No.	Client (full address of Applicant's client and telephone number)	Order No. and Date	Description and Quantity of ordered equipment/work s	Value of order (Rs. Lacs)	Brief details of equipment/works	Date of completion of delivery completion of delivery		Remarks indicating reasons for late, delivery if, any	Has the equipment been satisfactorily functioning? (Attach a certificate from the Engineer in charge)
						As per contract	Actual Likely completion date		
	1	2	3	4	5	6	7	8	9

Total volume of work on hand as on date, under execution/to be executed by you Rs. Lakhs ……………………………………..

Signature and seal of the authorised signatory of the applicant ______________________________________

(Please attach copies of certificates from your client)

Annexure A-2

Description of the industries surveyed in Uganda for Biomass Gasifier for heat applications

S. No.	Organisation	Physical & Postal Address
1	Victoria Engineering Limited	Plot 7/911, Kibira Road, Bugolobi P. O. Box 620, Kampala. Mob:0772460069
2	Nakawa Vocational Training Institute	P.O.Box 20121,Nakawa; Kampala Tel:0414220935 Mob: 0772464467
3	Suman Engineering Consn Co Ltd	Plot 18b, Kinya Road, Jinja P. O. Box 1847, Jinja Mob: 0772464467
4	Steel Works Ltd	Plot 403 Jinja Highway, Bweyogerere P. O. Box 25845, Kampala . Mob:0772744111
5	Casements (A) Ltd	Plot 86/90, 5th Street Ind. Area P. O. Box 4641, Kampala
6	Bansal Engineering Works	P.O.Box 30279 Makerer-Kampala Mob:0772403845
7	Mobile Agricultural and Technical Services	Plot 170, 6th Street, Industrial Area Mob:0772595755
8	Engineering Solutions Ltd	Plot 7, Spring Close off 5th Street; Mob 0772701239
9	John Lugendo and Company Ltd	Plot 321 Ndeeba, Masaka Road Mob:0772434363
10	Tonnet Agro-Engineering Company Ltd	Plot 699 Gayaza Road P.O.Box 35048, Kampala Mob:0772413754
11	Uganda Joinery and Steel Fabrication Ltd	Plot M445 Ntinda Industrial Area, Mob:0772757473
12	Ram Nand and Company Ltd	Plot 104/106, 6th Street Industrial Area Mob: 0772777232
13	Pioneer Engineering Works	Plot 276-277 Ntinda Industrial Area Mob 0712481990
14	David Engineering	Off Kireka Banda, Jinja Road P. O. Box 27996, Kampala
15	JBT Engineering	Plot 370 Makerere Kivulu Mob:0772488137
16	Specialised Welding Services	Plot 478/89, Kisugu-Muyenga ; Kampala Tel:0414510428

Annexure B-1

Questionnaire for survey in Ethiopia for solar PV

Objective of the Study: The specific objective is to identify, map and prioritize components and/or systems for solar PV technology over the short and long term that could be manufactured in Ethiopia.

1. Who are the key players producing/importing the solar photovoltaic application systems/components, if any, and what are the specification of such components and at what scale such production/import-taking place, from where (country and companies e.g. Japan and Sharp Solar)
2. What are the average prices at which the imports of the components take place?
3. Who do you think about the key players (current and probable E.g anyone dealing with designing/fabricating electronics products) in the solar photovoltaic systems manufacturing in Ethiopia and their claimed strengths and weaknesses?
4. Which of the components in a typical solar photovoltaic system (such as solar PV modules, battery, luminaries, charge controllers, solar inverters etc) do you think may be produced in the short term and long term?
   - And by which of the private companies operating in the SPV field?
5. Do you think the local companies will be able to produce/manufacture the complete SPV systems in the short term and long term?
6. Can you tell me some of the gaps in the SPV market in terms of demand, demand, investments, costs of production, financial, institutional, regulatory, technological, cultural and societal aspects
7. What are the developmental and business needs that have to be considered for local technology and balance of system component production?
8. What types of assistance do you think is required for strengthening the capacity of the manufacturing sector to produce the systems/components and if so to what extent
9. What are your organization's relative strengths and weaknesses in comparison to others in your field of business?
10. What are the relative market sizes of SPV products – sales volume, price of products and services, growth potential of the market, %share of each product within the category (Cannot be covered in the current methodology. Can be extrapolated by client, from data collected through the research.)
    - To estimate the current market size of various solar PV components, the following may be discussed with all respondents:
      i. What is the total sale of various components (specification, number, and turnover) by the respondent during the last 3 years – here pl ask what are the various solar products the respondent is selling, what are the sizes and specifications of such products and what is the retail cost of such system
      ii. What solar products are mostly sold (along with their tentative size and price) and who are the buyers of such products – domestic, institutions etc
      iii. What is the total market size as perceived by the respondent (last 3 years, pl try to collect data for last 3 years, component wise)
      iv. What will be the market size in the next 3-5 years (in terms of number, price and total volume) as perceived by the respondents
      v. What type of solar products are expected to dominate the market based on current demand as perceived by the respondents
      vi. What is the strengths and weakness of the country as a whole for production of solar PV modules and various components – perceived by the respondents

Annexure B-2

Description of the industries surveyed in Ethiopia for Solar PV systems

	Agency	Respondent Name	Contact
I. Government and UN Agencies			
1.	United Nations Human Settlements Programme	Dr Vincent N Kitio Chief, Energy Section, Water, Sanitation & Infrastructure Branch	Tel : +254 20 762 4343 Email : Vincent.kitio@unhabitat.org
2.	Ethiopian Rural Energy Development & Promotion Centre	Mr Kahisu Tadesse Yaebyo Director General	Tel: +251-11-5153689 Email: eesrc@ethionet.et
3.	Ethiopian Rural Energy Development & Promotion Centre	Mr Wosssenu Areda Alternative Energy Resources and Technologies Promotion and Dissemination Core Process Owner	Tel: +251 (0) 911- 694140 Email: wossenuareda@yahoo.com
4.	UNIDO	Dr David Tommy Director UNIDO Field Office in ETHIOPIA	Tel : +251- 11- 5514245 E-mail : Dtommy@unido.org
5.	Rural Electrification Fund	Mr Alemu Muleta Project Coordinator	Tel: +251 (0)11 5530459 Email: muleta_alemu@yahoo.com
6.	Addis Ababa Chamber of Commerce	Mr Getachew Regassa Secretary General	Tel : +251 550 934 Email: aachamber1@telecom.net.et
7.	MOFED –Ministry of Finance and Development	Mr Gulte Metaferia	Tel: +251 (0) 11 6618216
8.	Ethiopian Investment Agency	Mr Yohannes Latamo Promotion Team Coordinator	Tel: +251 551 9848 Email: eia.promotion.girum@gmail.com
II. Solar PV dealers			
9.	Solar 23 Development PLC	Mr Nabil Ishak General Manager	Tel: +251-11 8500024 / (0) 911517987 Email: Nabil.ishak@solar23.com
10.	Ethio-Dutch PLC	Mr Mr Adane W Michael	Tel: +251 (0)11 320021 Email,:solarman@ethionet.et
11.	Lydetco PLC	Mr Mr Senait Wake	Tel: +251 (0) 11 4660267 Lydetco@ethionet.et
12.	Free Energy Ethiopia PLC	Mr Yonas Teshome Manager	Tel: +251 (0) 911 2564 82 Email: free@ethionet.et
13.	BETA Engineering	Mr Yared Eshetu Marketing officer	Tel: + 251-11- 6510140 Email: route@ethionet.et
14.	Awash Battery	Mr Shyam Agarwal General Manager	Tel: +251 -11 – 4450 412 Email: feedback.awash@gmail.com
15.	IZURE	Dr Kirso Abeselom General Manager	Tel: +251 -11- 408068 Email: izur@ethionet.et
16.	Electric World	Mr Semir Zakaria Yusuf Manager	Tel: +251 (0) 11-156-9890 Email:electric.world@ethionet.et
17.	AHS Electric Pvt Ltd	Mr Amare Hadgu General Manager	Tel: +251- 1518018 Email:ahecc@ ethionet.et
18.	Avicom Trading PLC	Mr Biniam Gebrehiwet Managing Director	Tel: +251-11- 5540849 Email: biniam@avicom.com.et
19.	Direct Solar Energy Trading	Mr Enlefew Girma Manager	Tel: +251 911 208979 Email: samisolarenergy@yahoo.com
20.	Sat Solar Engineering PLC	Mr Adamu Bodja General Manager	Tel: +251 11 554 58 62 Email: satsolar@yahoo.com
21.	Konjo Battery	Interview of the key person could not be conducted, as appointment not yet provided.	
22.	Ever bright Solar	Interview of the Director is yet to be conducted, as he is out of country.	
III. Solar PV Consultant			
23.	SolaTech PLC	Dr. Ing. Tesfaye Bayou General Manager	Tel: +251 (0) 911 226556, 011 663 5603 Email: solatec@ethionet.et

24.	Megen Power Ltd	Mr Melessaw Shanko Managing Director	Tel: +251 116 296154 Email: MGP@ethionet.et
25.	Ethio Resource Group	Mr Hilawe Lakew Managing Director	Tel: +251 (0) 114 670802 Email: erg@ethionet.et
26.	Independent consultant	Prof Peter Adelmann Former CEO, Phocus AG	Tel : + 49 (0) 7346 449288 Email : peter.adelmann@beutelreusch.de
IV. NGOs			
27.	The Solar Energy Foundation	Mr Samson Tsegaye Country Director	Tel: +251 11 6181462 Samson@solar-energy-foundation.org
28.	German Technical Cooperation	Mr Joachim Gaube Head of AMES-E Project Mr Bayisa Abalti Coordinator, Solar PV	Tel : +251 - 116 - 463660 Email : joachim.gaube@gtz.de Tel:+ 251-116 - 451020 Email: bayisa.abalti@gtz.de
29.	Norwegian Church Aid	Mr Dawit Kebede Program Manager	Tel : +251-11-5512922 Email : dawitk@nca-ethiopia.org