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HOPE 87
Hundreds of Original Projects for Employment

UNIDO Project XA/BKF/98/A09

„Enhance the Competitiveness of the Agro-based Industries for Employment Generation“

(UNIDO Contract No. 99/184)

Manufacture and Delivery of a Pilot Fruit and Vegetable Drying Unit

Report on
Manufacture, Delivery, Installation and Training

1. Introduction

Burkina Faso is a landlocked country faced with a high degree of poverty: 45% of the population live below the poverty threshold with little resources to satisfy their basic needs. The majority of the population is dependent on agriculture which supports about 90% of the population. The main agricultural products include staple cereals (millet, sorghum, maize, rice, etc.), fruits and vegetables (with strong potential for the development of mangoes, papayas, green beans, tomatoes, eggplants, etc.) and shea and cashew nuts.

The food industry sector represents an important potential source for value-adding to the agro-pastoral production and has a strong potential for creation of employment and for export earnings for the country. Fruits and vegetables in view of their strong potential for the production of dried products (mangoes, tomatoes, onions, etc.), juices, syrups and tropical fruit jam has been identified as one of the products showing substantial potential for development.

UNIDO's programme in Burkina Faso aims at providing technical assistance in the development of competitive technologies for processing of fruits and vegetables with particular emphasis on drying. The first phase of the programme foresees the establishment of a pilot fruit and vegetable drying unit which uses solar energy as the main source of energy, complemented by diesel or gaz as the second source of energy.

The objective of the subcontract between UNIDO and HOPE'87 (contract No. 99/184) is to deliver in co-operation with UNIDO, the Groupement NAAM, Basnere and the local support institution CEAS ATTESTA, the following services:

1. Conceive and construct in Vienna, in close co-operation with UNIDO, a prototype of a Hybrid Drier which comprises an indirect solar drier and a supplementary heating system using diesel and /or gaz as source of energy.

2. Transport of the equipment to Burkina Faso and installation at the fruit and vegetable processing unit of the Groupement NAAM-Basnere in Ouahiagouya.

3. Training of the personnel of the Groupement NAAM and of the local support institution in the operation and maintenance of the Hybrid Drier.

2. Design and Construction in Vienna

The prototype was designed and constructed at the Department of Agricultural Engineering of the University of Agriculture in Vienna. The plant consists of an indirect solar drier and a supplementary heating system.

2.1 Indirect Solar Drier

The indirect solar drier is a modification of the HOPE´87/Landtechnik Multi-Purpose Solar Drier which was successfully tested under tropical and subtropical conditions in the Casamance, Senegal and now in application in three African countries viz. Senegal, Burkina Faso and Uganda. The indirect solar drier consists of the solar air collector, the photovoltaic system, and two drying chambers with 9 drying trays of $1m^2$ each. This gives a total drying area of $18m^2$. A two step radial fan is used to force the air through the air collector and the drying particles in the drying chambers.

2.1.2 Solar Air Collector

The air collector consists of six wooden boxes of 2.023m x 0.735m x 0.235m each. Each box contains a black painted absorber and insulation material at the base. The latter prevents heat losses through the bottom. The side walls are not insulated.

An important component of a solar collector is the absorber that absorbs the incoming radiation and convert it into heat. The absorber in this plant consists of two layers aluminium expanded-metal screen and single aluminium foil sheeting below. The latter fulfils two functions: it absorbs the incoming radiation transmitted by the porous absorber, and prevents the air from coming in contact with the glasswool insulation. A 4-mm thick colourless glass (0.74 m x 2 m) covers each box.

2.1.3 Drying Chamber

The drying chambers are also constructed of wood which is 20mm thick. The inner walls are insulated with aluminium foil to prevent the drying air from coming into contact with the wooden walls and to allow regular cleaning of the drying chambers. Each drying chamber contains 9 trays. The trays (1m x 1m) are made of wooden frame and aluminium mesh at the base.

The heated air from the air collector enters the chamber through the opening at the bottom of the side wall, passes upwards through the trays filled with the product, and exits through the opening at the top of the rear wall. Air filters placed at the entrance and exhaust openings protect the product against infestation by insects and contamination by dust.

2.1.3 Electric Fan and Photovoltaic System

A 2 step radial fan is applied for the air circulation in the air collector and drying chambers. It has a maximum air flow rate of 350m^3/h (1. step) and 600m^3 (2. step) at free blowing operation (i.e. low pressure resistance). The radial fan is driven by a 12V DC-motor with a power consumption of 65 and 145 W at step 1 and 2 respectively.

The fan is placed in a box (0.60m x 0.60m x 0.50m) with three inlet openings at the front and two outlet openings at the back. The inlet openings are connected with pipes (10 cm in diameter) to the air outlet of the air collector. The fan pumps the outside air first through the air collector and then through the pipes connecting the air collector with the fan box. The hot air is then forced through the two pipes connecting the box to the drying chambers. The pipes are provided with lockup-devices for the regulation of the hot air entering each drying chamber.

The **Photovoltaic system** consists of 4 PV-modules, 2 storage battery and a voltage regulator. The 4 modules (24V and 110 Wp each) are electrically connected in parallel to give a total performance of 440 Wp (4 x 110). (Wp= peak watt is the amount of power produced at standard reporting conditions (SRC), viz., receiver temperature of 25 °C and 1 kW/m^2 solar irradiance).

Two 12V lead-acid batteries store the voltage generated by the PV-modules. Each battery has a storage capacity of 120 Ah (ampere-hour). They are connected in series to give 24V and a total storage capacity of 240 Ah (2 x 120 Ah). The power generated by the PV-array is used to charge the batteries during periods of high insolation (at night and/or in periods of less insolation, the batteries will be charged with an electrical battery charger). The system regulator regulates the array output in order to prevent battery overcharge, overheating and the resulting decrease in battery life.

2.1.4 Supplementary Air Heater

The supplementary heating system uses a diesel-fuelled indirect heater to heat the drying air at night and/or during inclement weather (e.g. low solar radiation). The temperature of the air is regulated with a thermostat. The technical data of the air heater:

Voltage	24 V
Power consumption	36 W
Fuel consumption	0,46 l/h
Heating capacity	3,5 kW
Air flow rate of the fan	180 m^3/h

2.2 Operation Principal of the Hybrid Drier

The hybrid drier uses an indirect air collector to heat the ambient air during periods of high insolation. The incoming solar radiation (direct and diffuse components) incident on the collector surface is transmitted by the 4mm thick glass cover and is absorbed by the blackened aluminium expanded-metal screens which are thereby heated. The heat gained is transferred to the air pumped in by the fan and is transported to the drying particle in the drying chambers. The moist air exists through the exhaust opening at the top of the back wall.

At night and/ or during inclement weather (e.g. low solar radiation) the drying air is heated by the diesel-fuelled indirect heater. The supplementary heater uses a fan to pump the ambient air into the burner. The heated air is pumped into the fan box where it is mixed up with the additional air pumped in through the air collector by the 2 step radial fan (the supplementary air heater operates only in combination with the first step of the system fan).

3. Packaging and Shipment to Burkina Faso

The equipment was packed in four special packing crates which were collected by the shipping agent on the 19th of October 1999. Unfortunately, the vessel, Kintampo, did not depart Hamburg for Lomé until on the 27th of October 1999 instead of the scheduled 21st of October. The vessel arrived Lomé on the 13th of November 1999 as scheduled. Although the equipment arrived Ouagadougou a few days later (20.11), it wasn't released by the costume department until the 15th of December 1999. The unit finally arrived the working site, Ouahigouya, on the 16th of December 1999.

4 Installation and Training of the Personnel

4.1 Installation

As already mentioned above, all parts of the unit were prefabricated in Vienna. This did not only ease the international and local transport, but also the installation at the working site.

Plate 1 shows the preparation of the roof of the drying house. The house is oriented toward the south and is inclined at an angle of 15° in order to maximise the energy collection throughout the year and to allow for water runoff. It consists of three rooms. The drying chambers are placed in the center (drying room).

4.1.1 Installation of the Air collector

As already mentioned above, the air collector consists of six boxes (3 of the boxes have inlet and outlet openings at both ends while the other boxes have inlet openings at front ends and outlet openings at the base). Both sets are joined together to give a total length and breadth of 4.046m x 2.325 m. Plate 2 shows the bolting of boxes at the holes drilled at the upper and lower ends of the side walls. The bolting of the components was done on the ground for convenience and security reasons.

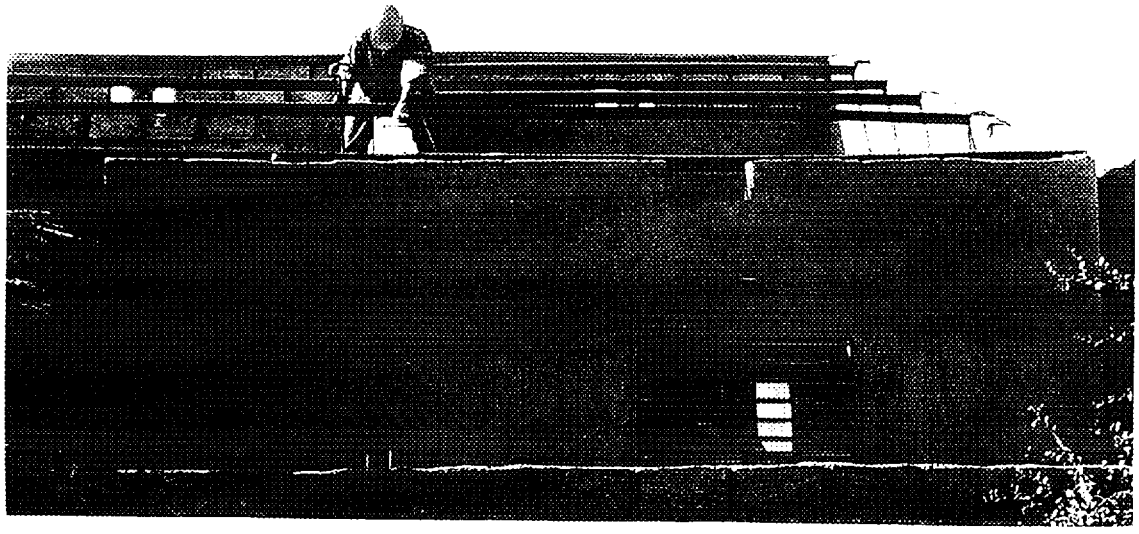

Plate 1: Preparation of the Roof of the Drying House

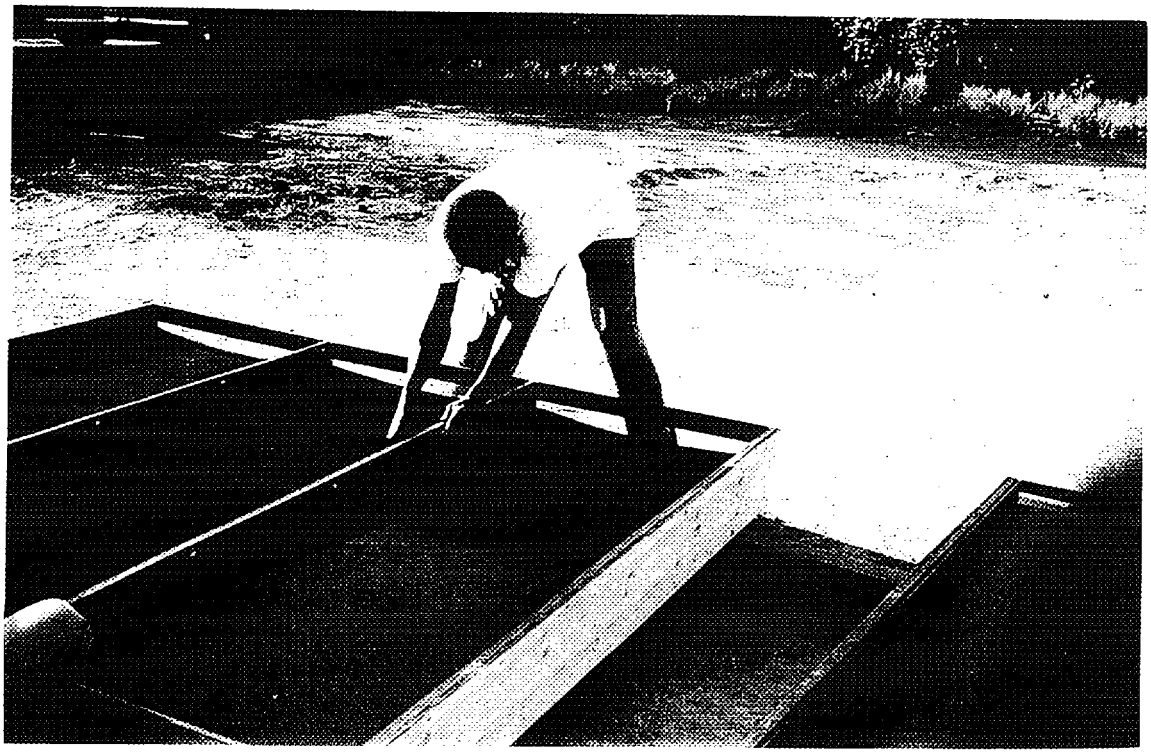

Plate 2: Assembling the Solar Air Collector

Subsequently, the boxes were lifted onto the roof of the drying house. First the set with the inlet and outlet openings at both ends (upper unit) was lifted up and bolted firmly to the roof beam. Afterwards the unit with the air outlet openings at the base was lifted up. Both units were first bolted together at the middle (this has to be properly done in order to avoid air and water leakage) before the lower unit was finally screwed to the roof beam.

The next step was the glazing of the air collector with the 4 mm thick colourless glass. This was done at the top of the roof for security reasons (breakage) and because of the high weight. The glass pieces (0.75m x 2m) were carefully placed one by one on the slot provided on each box. Finally they were carefully screwed to the wooden boxes with a 4 mm wide aluminium strip and sealed with silicon to prevent rain water from entering the air collector (Plate 3).

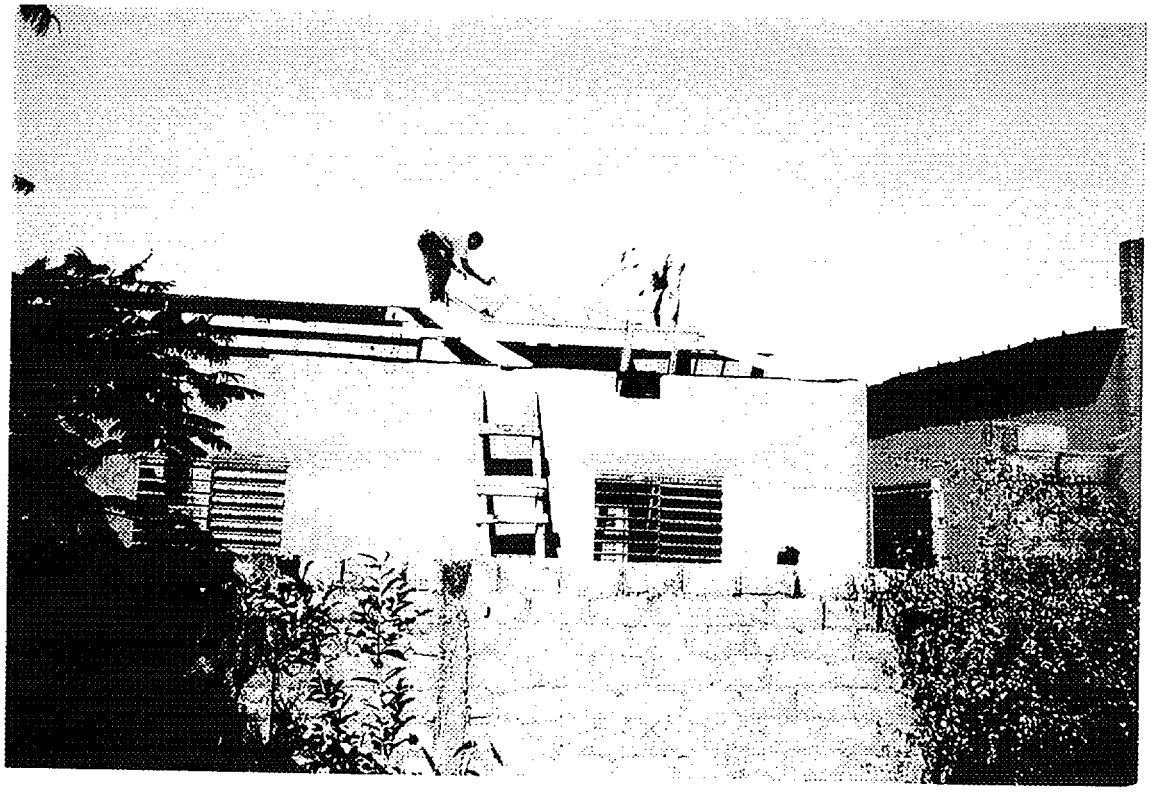

Plate 3: Glazing the Solar Air Collector

4.1.2 Installation of the Drying Chambers

Like the air collector, the chambers were prefabricated in Vienna to ease the assembling at the work site. First the components were selected and separated into right and left chamber:

Right chamber

1. One floor with supports on the bottom.
2. Right side wall.
3. Left side wall with inlet opening at the base.
4. Rear wall with outlet opening at the top.
5. Roof rear walls with outlet opening at the top.
6. Door.

Left chamber

1. One floor with supports on the bottom.
2. Left side wall.
3. Right side wall with inlet opening at the base.
4. Rear wall with outlet opening at the top.
5. Roof rear walls with outlet opening at the top.
6. Door.

The assembly-works consisted of screwing the components together. The side walls were first screwed to the bottom-plate at the screw-holes drilled at the base of the walls. Subsequently, the rear wall was screwed to the side walls and the roof to the top of the side and rear walls. Finally the door was fixed. The procedures were repeated for the second chamber.

4.1.3 Connection of the air collector to the Drying Chambers

First the chambers were arranged such that the outlet openings of both drying chambers fit to the exhaust holes on the house wall and the angle of the ducts connecting the fan box to the chambers isn't so sharp in order to avoid high pressure drops in the system. Plate 4 shows the connection of the air pipe. First the metallic supports were placed on the three outlet openings of the air collector and the inlet openings of the fan box. The pipes were then tied firmly to both supports. Subsequently the tubes connecting the fan box with the drying chambers were installed. Finally both pipes were insulated in order to minimise heat losses.

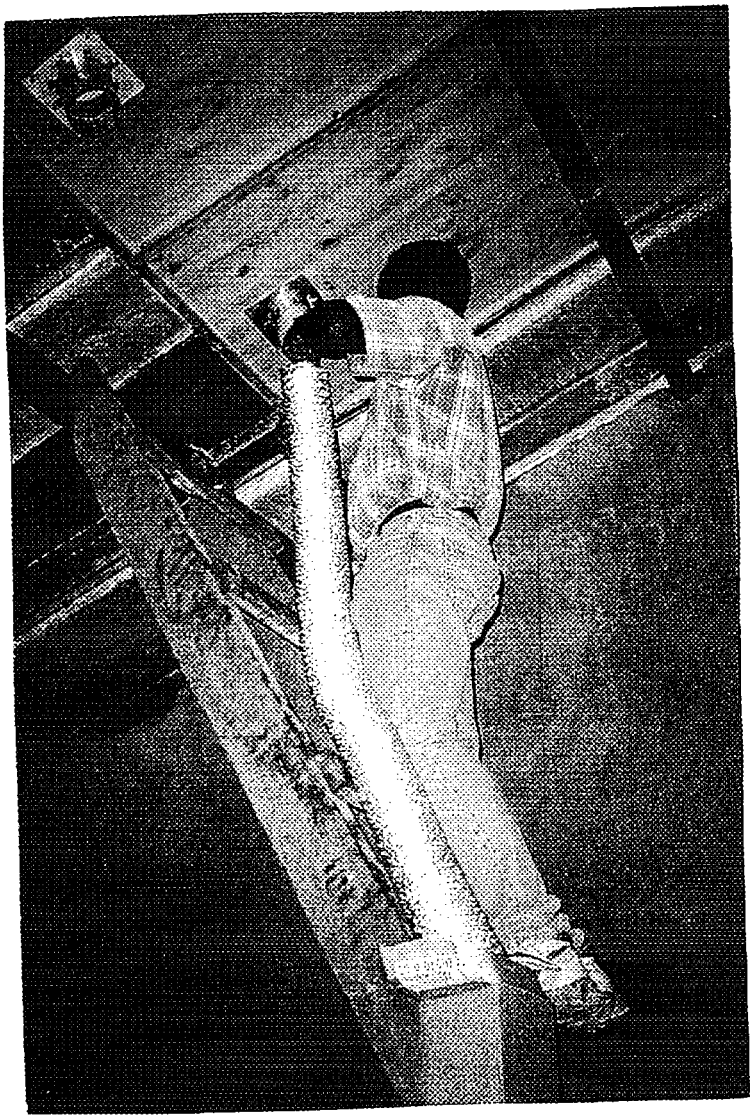

Plate 4: Pipe Connection

4.1.4 Electrical Installation of the PV-system

Plate 5 shows the installation of the PV-modules on the aluminium frame-structure. Afterwards the modules were connected. In order to avoid electrical shock harzard, the modules were first properly covered with opaque papers. Plate 6 shows the panel mounted on the roof of the drying house at the lower end of the air collector. Like the solar air collector, the PV-panel is south oriented and tilted at an angle of 15° for maximum energy collection. The space between the aluminium frame and the roofing sheet allows for convenient water runoff and air cooling of the panel. The latter is of importance, because high temperature has adverse effect on the cells' performance.

The next step was the electrical wiring: First the wires from the PV-panel were connected to the voltage regulator. Subsequently, the load (electric fan) and the batteries were connected (the appropriate positions for the various connections are symbolised on the regulator). Finally the batteries were filled with the electrolyte and the fuses were placed on the regulator and switch.

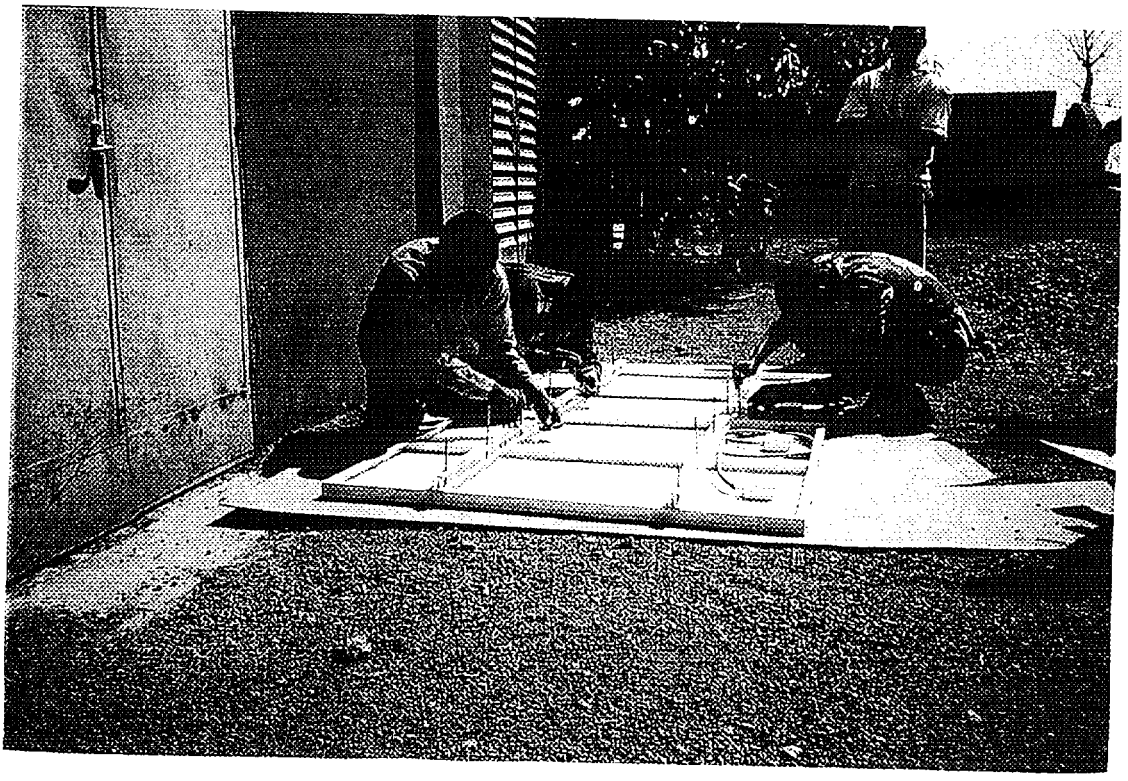

Plate 5: Installation of the PV-Modules

4.1.5 Installation of the Supplementary Heater

The diesel-fuelled supplementary heater is a normal car heater which is fabricated ready for assembly. The installation works are limited to the connection of the hot air duct to the fan box as well as the exhaust and the intake ducts.

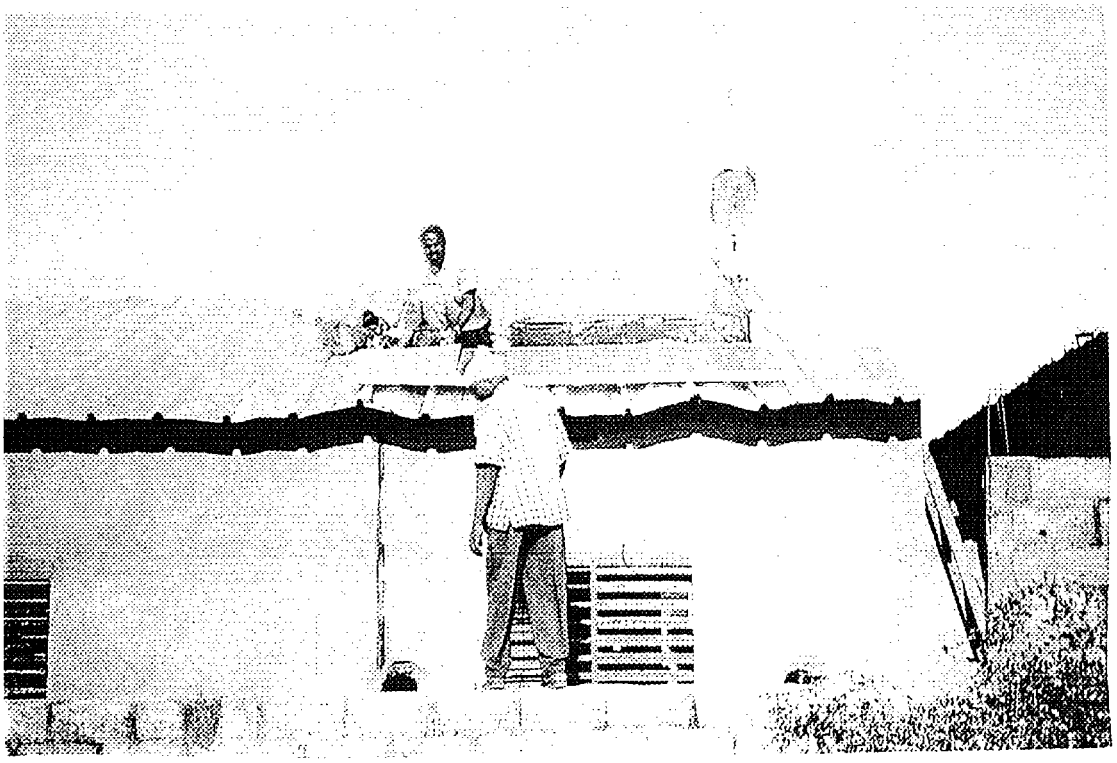

Plate 6: PV-Modules integrated on the Roof

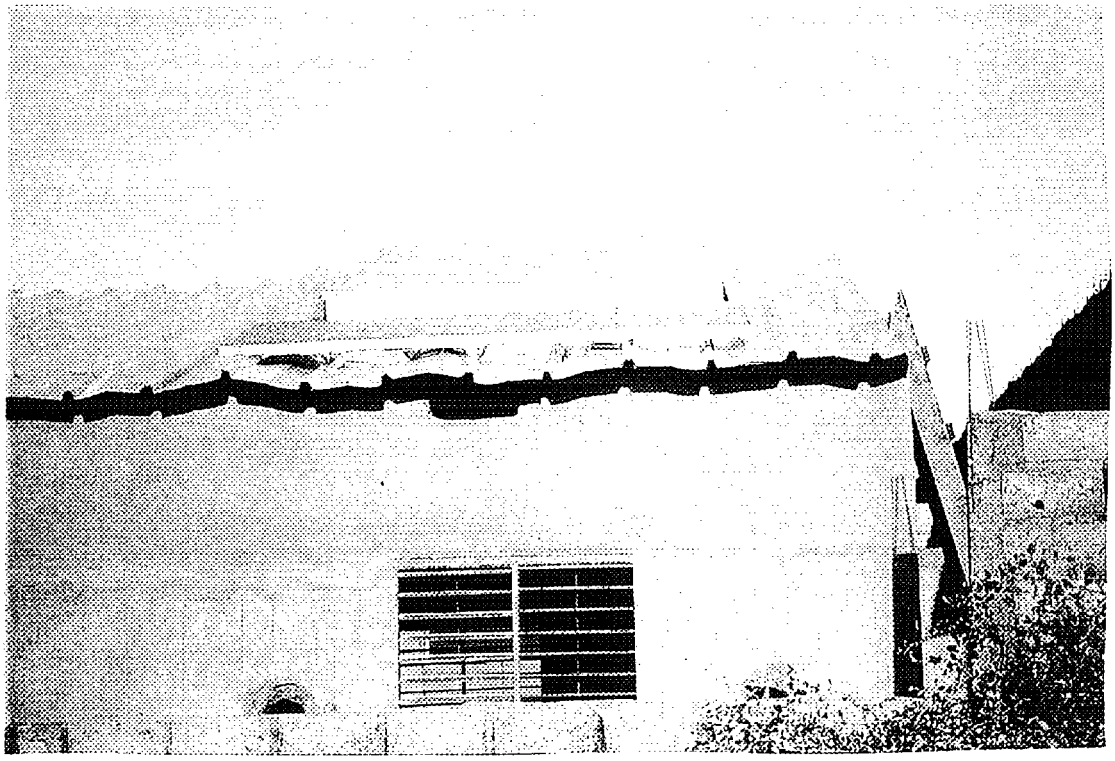

Plate 7: Solar Air Collector (background) and PV-Modules (foreground)

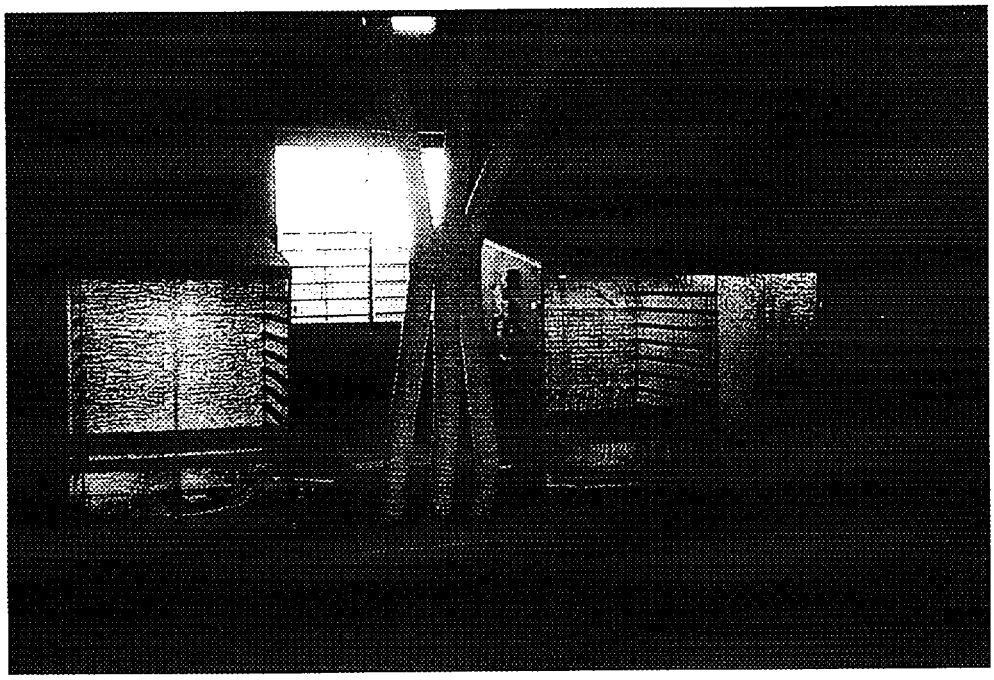

Plate 8: Drying Chambers, Fan Box (center) and Connecting Pipes

4.2 Training

4.2.1 Training on the Installation and Maintenance of the System

Two members of the staff of the local institution CEAS ATTESTA and 5 carpenters (2 journeymen and 3 apprentices) of the Groupement NAAM-Basnere were instructed in the installation of the components made of wood viz. air collector, drying chambers and the construction of the roof structure for appropriate integration of the unit on the roof. A local electrician chosen by the Groupement NAAM-Basnere was trained in the electrical installation (e.g. connection of the PV-modules, load and battery) and in the installation of the diesel-fuelled heater.

Both training units were done in through "Learning by Doing". Prior to the practical implementation of the various installation procedures described above, a theoretical explanation was conducted. The installation work was followed by a one-day seminar. This consisted of the following:

Basics of solar technology (sun as the source of energy, solar radiation on a horizontal surface, etc.).
Classification of solar dryers.

Operational principle of various solar dryers.
Description of the hybrid solar drier.
Operational principle of the hybrid drier.
Components of the air collector (absorber etc.).
Components of the PV-system.
Installation and importance of the electrical fan.
Function of the supplementary heater.

4.2.2 Training in the Operation and Maintenance

An advantage of the system lies in its simplicity in construction, operation and maintenance. The diesel-fuelled heater is also user-friendly.

A group of 5 women and two young men was trained in the operation of the hybrid system. The training on the operation consisted of the switching on and off of the electrical fan, loading of the drying trays in the drying chambers and attaching of the filters. This was easily understood by the trainees who were, at the end of the first day, in the position to operate the system by themselves.

Like the operation, the maintenance of the hybrid drier is simple. Two young men in the drying group and a local electrician were instructed in the maintenance of the system. The training consisted of the following:

1. Washing of the glass cover (air collector) and module surface.
2. Checking of the wiring and connectors for cracking, rodent damage etc.
3. Checking of the modules for cracked cells, interconnect corrosion, etc.
4. Checking of battery electrolyte level and adding of water; cleaning of the battery terminals and tightening of the connections.
5. Checking of the fuses and replacing them when necessary.

5. Conclusion

A prototype of a hybrid fruit and vegetable drying unit which comprises an indirect solar drier and supplementary air heating system using diesel as source of energy was designed, manufactured and delivered to the Groupement NAAM-Basnere, Burkina Faso as specified in the contract (contract No. 99/184) between UNIDO and HOPE´87.

The installation of the Unit was done in the later part of December 1999. Two members of the staff of the local support institution CEAS ATTESTA, and 5 carpenters of the Groupement NAAM were trained in the installation and maintenance of the air collector and drying chambers both of wood construction. A local electrician and two members of the drying personnel were instructed in the electrical installation and maintenance of the PV-System (PV-modules, battery, voltage regulator, etc.), the electrical fan and the diesel-fuelled heater. The practical training was followed by a one-day theoretical seminar.

The drying personnel (5 women and 2 young men) was instructed in the operation and maintenance (washing of the glass cover and PV-modules, checking of the battery electrolyte level and adding water etc.) of the unit.

Terms of Reference for the subcontract

1. Objective of the contract:

The objective of the subcontract is to provide the services described hereunder.

1. Conceive and construct in Vienna, in close co-operation with UNIDO, a prototype of a hybrid drier which comprises an indirect solar drier and a supplementary heating system using diesel and /or gaz as source of energy.

2. The solar drier should consist of:
   - A solar air collector (collection area: 10 m2)
   - A photovoltaic system for electricity generation: 3 modules (24V, 110Wp) 2 accumulators (100 Ah each, 12V), regulator and inverter to convert DC output in AC (!2V DC to 220V AC);
   - An electric fan (2 steps): Voltage of the DC motor: 12V; power consumption: 65 W and 145 W at step 1 and 2 respectively;
   - Two drying chambers with 18 drying trays (total drying area: 18 m2);

3. Supplementary heating component: Use of diesel and/ or gaz; provision of indirect air heating with automatic air temperature regulation and complete electronic control through a micro-processor. The maintenance of the system should be easy and user-friendly;

4. Transport of the equipment to Burkina Faso and installation at the fruit and vegetable processing unit of the Groupement NAAM - Basnere in Ouhiagouya.

5 Training of the personnel of the Groupement NAAM and the local support institution in the operation and maintenance of the drier.