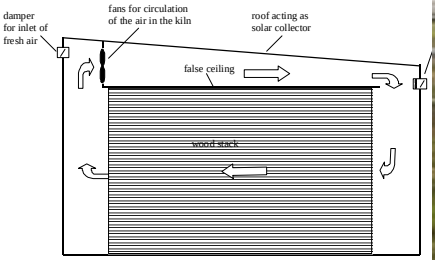
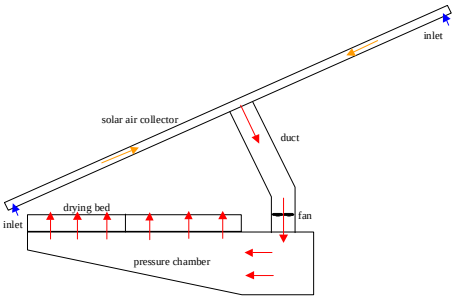
Solar drying in Ghana
Final report





Solar Energy Centre Denmark
Danish Technological Institute

SEC-R-24

Solar drying in Ghana
Final report

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July 2002

Preface

The report finalizes the project "Test and Research Project into the Drying of Food and Wood Products with Solar Heat" financed by Danida (Danish International Development Assistance) via the Danish Embassy in Ghana. The project was established based on an initiative by the Energy Commission of Ghana.

The present report is mainly based on the other reports produced within the project and summarizes these – the reports are listed in chapter 9. Please refer to these for further details if necessary, however, in order to gain full benefit of the present report it is advised to read the reports from chapter 9, which is referred to in the text. It is possible to download the reports from the internet.

Solar drying in Ghana – Final report
1st printing, 1st edition

Energy division

ISBN: 87-7756-659-9
ISSN: 1600-3780

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1. Background for the project

The project "Test and research project into the drying of food and wood products with solar heat" financed by Danida via the Danish Embassy in Ghana was started in the summer of 1999. The administrator of the project was the Ghanaian Energy Commission. Solar Energy Centre Denmark, the Danish Technological Institute acted as daily co-ordinator of the project while DENG Ltd. co-ordinated the Ghanaian participation of the project.

The following is a copy of part of the application for the project and gives the background for the project.

1.1 *"Background*

A very large proportion of the food products in developing countries like Ghana is destroyed before they reach the market. This waste may be reduced considerably if the products are dried before they are shipped to the market.

Some food products are already today dried by being put out on the ground in the sun. This is, however, a slow process which often takes many days and the products are not dried uniformly. Food products as e.g. fish and meat are exposed to attack from bacteria which may make them dangerous to eat. Crops are exposed to attacks from insects and fungus and may be polluted by e.g. dust. Consequently the quality of the products is decreased leading to a lower profit for the countries if the crops are meant for export.

The policy in Ghana is that wood should be manufactured to some extend in the country which lead to a demand for drying wood.

Crop drying

In general, farmers have a problem in having their crops dried fast, efficiently, economically and environmentally correct. Drying on the ground by the sun is currently the most used method.

Most farmers cannot afford to import expensive mechanical drying equipment, which is either electricity or diesel engine driven, with the additional financial burden of maintenance, fuel, electricity and other running expenses. Apart from the environmental problems.

Many more farmers will be able to increase their output if a relatively cheap solar dryer for crops is made available with the additional benefit of very low running expenses. The success of such equipment would depend upon the final cost of the solar dryer, each farmer's financial situation, on the bank and the equipment manufacturer, and in some cases, donor agencies would become some of the key players.

Wood drying

For most small scale saw millers and furniture manufacturers in Ghana, the most expensive cost element in their production is the drying of wood. Small scale saw miller have installed kilns powered by diesel engine or electricity whereas small scale furniture manufactures are relying upon the drying of the wood in the sun, which is very tedious. The alternative for them

is to have the wood dried by bigger saw millers which increases the cost of the wood by as much as 300%.

Use of solar dryers would enable small to medium size saw millers and furniture manufactures to increase their output and operate much more competitively.

Fish drying

Drying of fish after harvesting is an important stage in the processing and preservation of fish for the domestic and export market. Yet. it is at this stage where most of the fish is handled in an unhygienic manner. Traditionally, processing and preservation is done by sun drying where the fish is spread out on the ground, exposing it to the sun during the day. In fact the open-air drying technique is one of the oldest uses to which solar energy has been put to, in rural areas of Ghana.

Open-air drying is appropriate in some cases but carries major disadvantages in others. For instance, drying temperatures cannot be controlled, and product quality is poor because of contamination with flies and bacteria. The controlled conditions in a solar dryer may considerably increase the quality of the dried fish.

1.2 Description of the project

The aim of the project is to adjust the Danish expertise within the area of solar air heating systems, drying of grain by solar air heating, drying of crops and wood and subsequently transfer it to Ghana.

Solar drying is a well proven process but it is necessary to adapt the concept to the local conditions and demands.

The project will be based on the given conditions in Ghana - existing technology, available materials and labour, climate (solar irradiation, ambient temperature and ambient humidity) and the demand for drying of food and wood, etc. Based on this, solar air heating systems will be optimized for drying different products. The optimization will deal with the size of the solar air collector, how to establish the air flow, how the drying chamber should be designed (for different products) in order to minimize the drying time and maximize the drying volume, how the products should be prepared for the drying, is it advisable to introduce heat recovery on the exhaust air from the drying chamber, etc.

It is necessary to have a fan in the system in order to maximize the drying quality and to minimize the drying time. The air flow should be variable so an optimal drying temperature may be reached. It is only necessary to have a fan with a low power consumption which may be driven by a solar cell panel or a small generator driven by a motor. If a motor is chosen this may also be utilized to cover other of the demands for electricity of the drying plant - e.g. light and packing of the dried products. The waste heat from the motor may be utilized for preheating the air to the drying systems.

It is the aim that the drying time especially for food is reduced to one day so that it do not absorb humidity during the night, which will lead to increased drying time and to the risk that the products are damaged.

It is the goal to perform an economical/technical full scale test of a flexible system in the form of three test units. The first test unit (for crop drying) will be built in Denmark on the container concept, where the drying chamber is a small container. The solar air collector and ventilation system will be packed in this container and shipped to Ghana after test in Denmark. The system will then be assembled and used as model for building of two more test units in Ghana. The two local test units will as much as possible be build from materials available in Ghana – including the solar collector, fan, PV, etc in order to show that it is possible to build solar drying facilities in Ghana. The three test units will be tested in Ghana - two for drying of food products (crops and fish) and one for drying of wood. Based on the experience with the test units, dissemination of the concept in Ghana will be carried out.

1.3 Project group

In Denmark the project group consists of the Solar Energy Centre Denmark, Danish Technological Institute (expertise in solar air heating systems), Aidt Miljø (manufacture of solar air heating systems also for drying of grain), Department of Agricultural Engineering, Danish Institute of Agricultural Sciences (expertise in drying of crops) and Wood Technology, Danish Technological Institute (expertise in drying of wood).

The partners in Ghana are DENG (production, sale and installation of energy technology including solar heating systems), University of Kumasi and ECON KOAD Consultancy Ltd. (experienced in performing feasibility studies)."

1.4 The actual project

The progress and deliverables of the actual project followed rather closely the above description from the application as the following chapters show. Main difference between the actual project and the above description are that the following things was not part of the project: heat exchanger between exhaust and inlet air, diesel motor for driving the fans and drying chambers made of containers. These topics turned out not to be worth while investigating.

During the project the Ghanaian consultants University of Kumasi and ECON KOAD was replaced by FORIG and FADAGOD Ltd.

2. The organization and progress of the project

The project was divided in different subtasks with different participants as listed below – from the proposal for the project:

- Project management: Solar Energy Centre Denmark, Danish Technological Institute. Team Leader in Ghana: DENG.

- Necessary information on climate, demand and data on crops, fish and wood: University of Kumasi and ECON KOAD Consultancy.

- Determination of drying condition incl. design of the drying chamber for drying of crops based on a survey in Ghana: Department of Agricultural Engineering, Danish Institute of Agricultural Sciences.

- Determination of drying condition incl. design of the drying chamber for drying of wood based on a survey in Ghana: Wood Technology, Danish Technological Institute.

- Optimization of drying condition for drying of fish based on a survey in Ghana using a test unit equal to the unit for crop drying: DENG.

- Optimization of the drying system based on weather data from Ghana and the drying conditions for the different products: Solar Energy Center Denmark, Danish Technological Institute, Aidt Miljø, Department of Agricultural Engineering, Danish Institute of Agricultural Sciences, Wood Technology, Danish Technological Institute and DENG.

- Construction and test of the first test units: Aidt Miljø, Solar Energy Centre Denmark, Danish Technological Institute and Department of Agricultural Engineering, Danish Institute of Agricultural Sciences.

- Construction of the two other local test units is Ghana: DENG.

- Test, demonstration and dissemination of the technology in Ghana: DENG and University of Kumasi.

The implementation plan from the application is listed first in Appendix A. After the kick-off meeting at the Ghanaian Energy Commission in October 1999 the implementation plan was revised on December 20, 1999 (also listed in Appendix A) in order to more clearly correspond with the decisions made at the kick-off meeting and based on the survey performed in October 1999.

Minor adjustments have later been made to the implementation plan – in June 2000, October and December 2001 in order to reflect the progress of the project. These new implementation plans are also listed in Appendix A.

In order to give an impression of the progress of the project the progress report for both the Danish and Ghanaian partners are listed in Appendix B and C respectively. The progress reports are listed without annexes.

Some problems have occurred during the project but as seen in Appendix A-C the project has progressed rather smoothly and has most of the time been on schedule.

The deliverables of the project – prototypes, test results, reports, etc. - have mainly been delivered on time and in a good quality. The following chapters describe briefly the different solar dryers, which have been developed and erected. Further the results and experience from the tests carried out on the dryers are described. For more details please refer to the reports from the projects listed in chapter 9.

The main impression of the project is that it has been successful.

3. Survey

A survey was conducted in the period October 4-8 1999. The aim of the survey was to investigate the need for drying of food and wood in Ghana and the already existing experience on solar drying in order to form a basis for the initial decisions within the project concerning the location of three demonstration solar dryers for crops, fish and wood, which species to dry and the type of solar dryers.

The project dealt with transfer of knowledge in the field of drying of crops and wood and solar air heating systems from Denmark to Ghana. The aim of the survey was, therefore, also to give the Danish experts an impression of the conditions in Ghana in order to facilitate an appropriate design of the solar dryers. Three of the four Danish partners participated in the survey. The fourth Danish partner - the manufacture of solar heating systems Aidt Miljø – was already familiar with the conditions in Ghana due to an earlier project in Ghana.

As part of the visit by the Danish experts the Ghanaian Energy Commission hosted two kick-off meetings of the project. At the first meeting the plans for the survey were discusses and agreed. At the second meeting the findings from the survey were discussed and the plans for the project adjusted accordingly

The survey was planed by the Energy Commission of Ghana, the Ghanaian partner and consultants: DENG, University of Science & Technology, Kumasi and Econkoad. The visits gave the Danish experts a good overview of the situation in Ghana in the field of post harvesting of crops, handling of fish, drying and manufacturing of wood and existing experience on solar drying. The schedules included a large variety of different information and impressions e.g. ranging from large sawmill to small carpenters and workshops.

The collected information and impressions from the survey are described in the report (Jensen, Frank and Kristensen, 1999). It is believed that the survey did form the best possible basis for the further work of the project as the Danish partners did obtain a good impression of the need and possibilities for solar drying in Ghana. Further several valuable contacts were established during the survey.

Based on the findings from the survey the three types of solar dryers were designed. The following chapters describe briefly the development and test of the solar dryers – further information may be obtained in the reports referred to in the chapters.

4. Design of the solar crop dryer and the fish dryer

It was from the start the intention that the solar fish dryer should be based on the same design as the solar crop dryer. For this reason only the design of the solar dryer will be described here.

Based on a survey in Ghana (Jensen, Frank and Kristensen, 1999) it was decided to develop a dryer for drying of maize for seed as the increase in value of the crop due to the drying here would be high – the dryer may, however, also be used to dry other crops or other items. The capacity of the dryer was defined to be 500 kg having a collector area of approx. 25 m². It was decided to let the dryer consist of 5 separate units each with a transparent collector area of 4.77 m² and a capacity of approx. 100 kg. The modulized concept has several benefits: If one drying bed is operated improperly this will not affect the total quantity of crops being dried at that time. It is possible to dry different crops (creating different pressure drop) side by side without risking that the crop with the highest pressure drop will be dried improperly. Small dc fans are often cheaper than larger dc fans. The system will be less complex, and an even air distribution over the drying bed is easier obtainable. Finally it is possible to start with only one unit and then gradually increase the capacity of the solar dryer - this will make it easier to invest in a solar dryer.

It was further decided that the fans of the dryer should be powered directly by PV-panels in order to make the dryer independent of an often unreliable, missing or expensive grid.

Figure 4.1 shows the principle of the solar crop dryer while figure 4.2 shows a picture of the first prototype of the dryer.

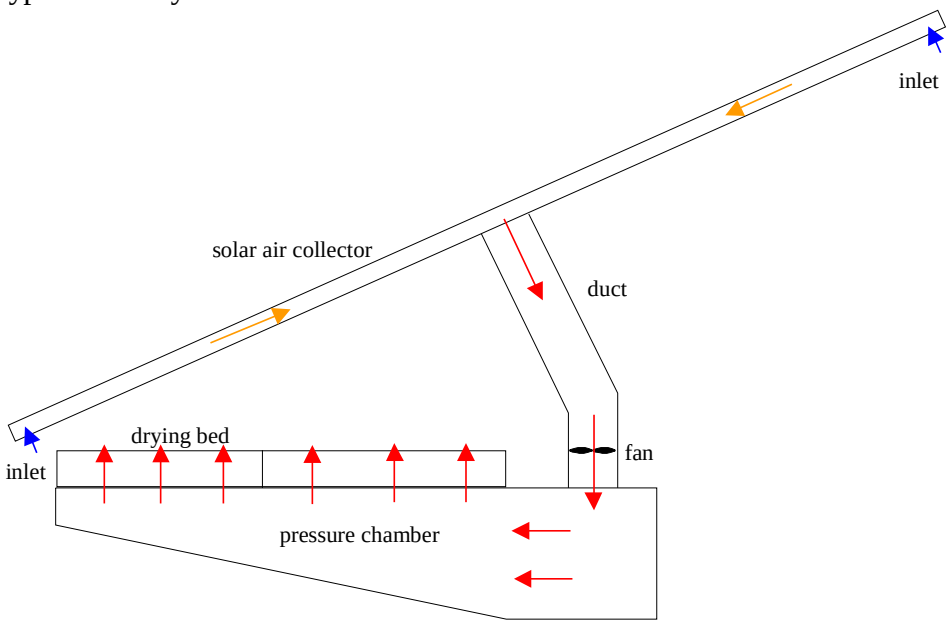


Figure 4.1. The principle of the concept in the solar crop dryer. The coloured arrows show the air stream through the system.

Figure 4.2. Photo of the first design of the solar crop dryer – one unit.

The final components of the solar crop dryer were:

- Collector: Outer dimensions: 4900 x 1070 mm². Transparent area: 4.77 m². Cover: 10 mm double walled ribbed UV-stabilized polycarbonate. Absorber: Black felt mat. Air intake at the back of the PV-panels at both ends and air outlet in the middle at the back.
- Fan: 300 m³/h at 40 Pa. 12 V dc motor. Power: 12 W at 12 V.
- PV: 2 panels of 12 V, 14 W_p.
- Duct between collector and drying bed: metal ducting with the smallest cross section of 0.031 m².
- Drying bed: 6 trays made of plastic: 600 x 400 x 278 mm³ (outer dimensions).

Based on tests the design was developed successively – please refer to (Jensen, Kristensen and Forman, 2001) for further details.

The main problem with a PV powered solar crop dryer is the fan: the fan should be inexpensive, durable and produce high flow rates at a high pressure while having a low power consumption in order to keep the prise of the solar crop dryer down and at the same time ensure an efficient drying process. A compromise is obviously necessary.

In order to limit the necessary size of the PV-panels the flow rate through the crop was decreased considerably compared to conventional dryers. With the air flow in the design case of 300 m³/h per unit the air speed through the drying bed was 0.06 m/s. This is very low compared to the 0.3-0.7 m/s in conventional cross flow dryers and also low compared to the 0.1 m/s in conventional platform dryers. The low air speed, however, results in a longer drying time. With the chosen concept it is not possible to try the maize in one day – two-three day are needed.

The first sets of experiments showed that the air flow rate was too low. The design of the collector and ductworks was, therefore, altered in order to decrease the pressure drop across the system. The pressure drop was in fact decreased by more than 50%. Air flow rates of up to 500 m^3/h was obtained at low ambient temperatures. However, it was shown that the air flow rate did decrease rather fast by increasing ambient temperature – i.e. by increasing PV cell temperatures. Several measures to cool the PV-panels and to increase the power from the PV-panels were investigated with some results. However, it was found that a thorough solution of the problem would be too costly.

The flow rate directly influences the air temperature to the drying bed. As maize for seed was chosen to be the main object for the dryer the air temperature to the drying bed should not exceed 45°C. Together with the above-described investigations measures to reduce the air temperature to the drying bed without decreasing the overall performance of the dryer were investigates.

The description of the experiments carried out in Denmark with the solar crop dryer and the results are fully described in (Jensen, Kristensen and Forman, 2000).

The tests on the prototype dryers showed that under favourable conditions (rather low ambient humidity and high solar radiation) it was possible to dry 120 kg of maize from a water content of 20% down to 10% (which was the aim) in 1½ day in one unit of the solar crop dryer. It should, therefore, be possible to dry 100-120 kg in 2-3 days in Ghana per unit which early in the project was set as a goal.

Base on the investigations in Denmark it was decided to erect a solar crop dryer consisting of 5 modules and a solar fish dryer of 1 module in Ghana. The five modules for the solar crop dryer was produced in Denmark and shipped to Ghana while only the collector of the fish dryer was produced in Denmark and shipped (together with different parts for the fish dryer and the solar crop dryer) to Ghana. The dryers were shipped for Ghana by the beginning of August 2000.

5. Design of the solar wood dryers

While the design process for the solar crop dryer was rather straight forward it was difficult to come to a consensus among the partners of the project for the solar wood dryer. The option was between a forced open-air solar dryer and a solar kiln.

Based on the weather data obtained by Professor Akufo, University of Science & Technology, Kumasi (Jensen, 2000) the Danish wood experts recommended a forced open air dryer, with ambient air driven by PV powered fans as seen in figures 5.1-2.

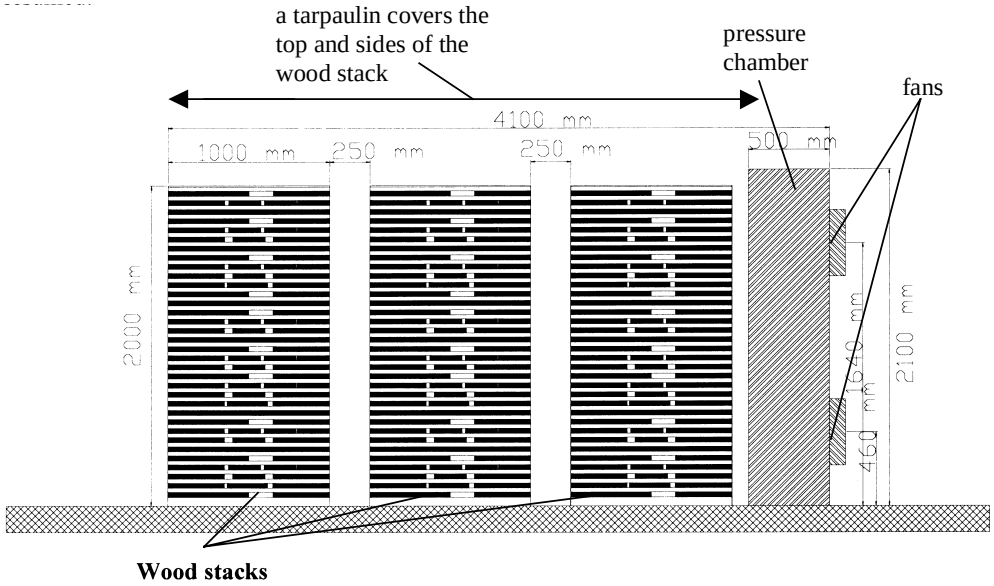


Figure 5.1. The principle of the forced open-air dryer.

Figure 5.2. The pressure chamber of the forced open air dryer with fans and the tarpaulin.

The design is very simple. It consists as seen in figure 5.1 of a pressure chamber with 6 dc 50 W fans as seen in figure 5.2. The wood stack is located in front of the pressure chamber. A tarpaulin mounted to the pressure chamber is pulled over the wood stack in order to ensured that the air is only sucked through the wood stack. The fans are powered by an array of PV-panels. More details on the forced open air dryer may be found in (Frank, 2000)

However, other measurements in Monkoadzehave show that the humidity of the ambient air is far lower than given by Professor Akufo meaning than a forced open-air dryer would be of little benefit. Control of the temperature and humidity level of the air surrounding the wood is, therefore, of major importance. A design of a solar kiln was, therefore, also proposed – figure 5.3.

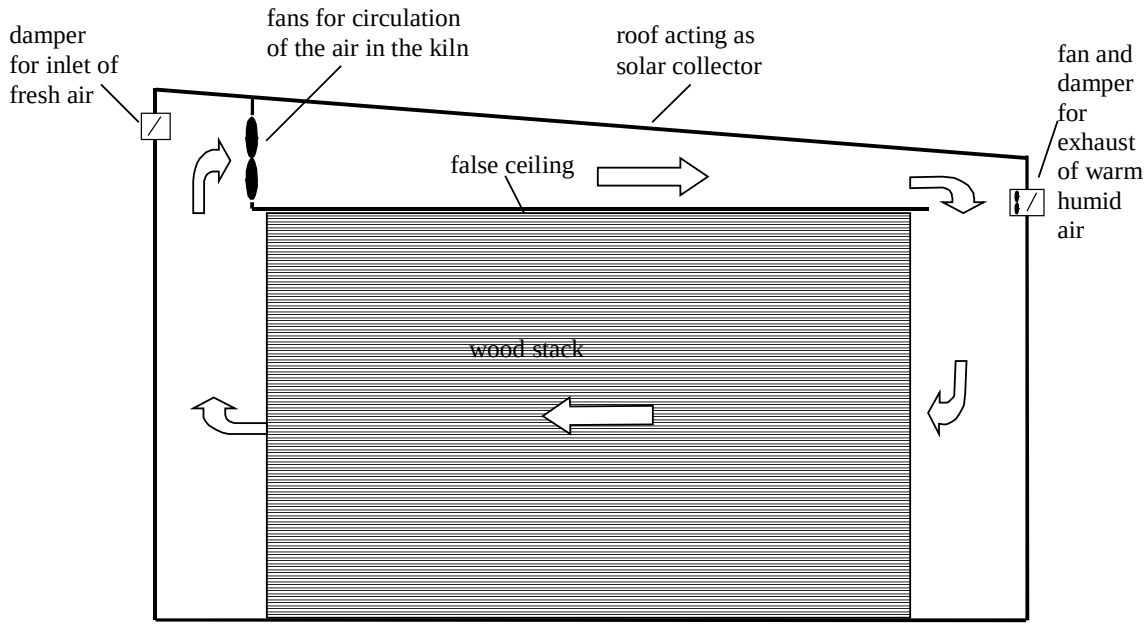


Figure 5.3. The principle of the solar kiln.

As no consensus could be reached on which design to chose it was decided to build both in Ghana – however, in such a way that each of the designs easily could be turned into the other design. It was decided that the solar wood dryers each should be able to contain 10 m³ wood.

Based on the test on the forced open-air dryer (Jensen, 2002) it was decided to convert it into a kiln like the original kiln as the forced open-air dryer turned out to be of little use due to too low ambient humidities, which made the dryer difficult to control and damaged the wood.

The components of the <u>two</u> kilns are:

<u>Original kiln:</u>

Fans: 1 dc fan for day-time circulation, diameter: 60 cm, max power: 550 W
1 dc fan for night(and day)-time circulation, diameter: 40 cm (16”), max power: 50 W (for further details see (Frank, 2000)). The fan is also runing during the day directly coupled to the PV-panels as the large day-time fan.
1 dc fan for exhaust, diameter: 11 cm, max power: 7 W

PV-panel: 14 panels of 60 W_p each = 840 W_p

Battery: 260 Ah charged by a one 60 W_p PV-panel. The battery charge the 50 W night-time fan during periods with no or very low solar radiation.

New kiln:

Fans: 6 dc fans for day-time circulation, diameter: 40 cm (16”), max power: 50 W (for further details see (Frank, 2000))
One of the above fans is used for night-time circulation.
1 dc fan for exhaust, diameter: 11 cm, max power: 5 W

PV-panel: 30 panels of 14 W_p each = 420 W_p

Battery: 260 Ah charged by a one 60 W_p PV-panel. The battery charge the 50 W night-time fan during periods with no or very low solar radiation.

The black painted roof and walls of the kilns acts as solar collectors for heating the air in the kilns. The area of the roof is about 12 m² per kiln.

6. The solar dryers in Ghana

Base on surveys conducted by the Ghanaian partners the locations for the solar dryers were defined:

- Solar crop dryer: The solar crop dryer was erected at Silwood Farms at Pokuase about 30 km north of Accra. Silwood Farms grows primarily maize for seed and pineapples.

- Solar fish dryer: The solar fish dryer was erected at Elite Enterprise Ltd. at Tema about 35 km east-north-east of Accra. Elite Enterprise Ltd. buys and smokes fish.

- Solar wood dryers: The solar wood dryers were erected at Clipper Design Ltd. at Mankoadze about 65 km west-south-west of Accra. Clipper Design Ltd. produces mainly doors.

Figures 6.1-2 show the solar crop dryer, figures 6.3-4 the solar fish dryer while figures 5.5-6 show the solar wood dryers. For more details on the solar dryers erected in Ghana please refer to (Jensen, 2001 and Jensen et al, 2002).

The solar crop dryer and the solar fish dryer were put into operation in January 2001 while the solar wood dryers were started in March 2001. The forced open-air dryer was in December 2001 converted into a solar kiln.

Figure 6.1. The solar crop dryer seen from the south.

Figure 6.2. The five drying units inside the building containing the solar crop dryer.

Figure 6.3. The solar fish dryer seen from the south.

Figure 6.4. The interior of the hut containing the drying bed of the solar fish dryer.

Figure 6.5. The two chambers for the open-air wood dryer (to the right) and the solar kiln (to the left) seen from the north.

Figure 6.6. The PV-panel of the two wood dryer. The PV arrays are movable in order to allow for cleaning of the PV-panels and later tracking of the sun.

The impression from the inspections in January 2001 (Jensen, 2001) and March 2002 (Jensen et al, 2002) reviled that the solar dryers show good craftsmanship and that they nicely represent the project.

For further details on the solar air dryers in Ghana please refer to (Frank, 2000), (Jensen, Kristensen and Forman, 2001), (Jensen, 2001) and (Jensen et al, 2002).

7. Tests and experience from the solar dryers in Ghana

The results from the tests of the solar dryers in Ghana are summarized in the following – for further details please refer to (Jensen et al, 2002), which contains the detailed results of the tests.

7.1. Solar crop dryer

The main problem with a PV powered solar crop dryer is as earlier mentioned the fan: the fan should be in-expensive, durable and produce high flow rates at a high pressure while having a low power consumption in order to keep the prise of the solar crop dryer down and at the same time ensure an efficient drying process. A compromise is obviously necessary.

In order to limit the necessary size of the PV-panels the flow rate through the crop was decreased considerably compared to conventional dryers. With the air flow in the design case of 300 m^3/h per unit the air speed through the drying bed was 0.06 m/s. This is very low compared to the 0.3-0.7 m/s in conventional cross flow dryers and also low compared to the 0.1 m/s in conventional platform dryers. The low flow rate and the possibility of only drying during daytime increases the drying time compared to conventional dryers. With the chosen concept it is not possible to dry the maize within one day. The aim was, therefore, altered to a drying time of 2-3 days.

In general, the results from the drying tests at Silwood farms have been satisfactory. It is thus possible to dry maize for seed in the solar crop dryer. Germination tests on maize dried in the solar crop dryer have shown high germination percentages. The germination percentage was measured to 96%, which is very high.

The aim of the project was to reduce the initial moisture content of about 600 kg of maize from 22 to 10% within 2-3 days. The results from the tests during the minor maize season of January to February were as expected and in good accordance with the theoretical estimation and the goal of the project. Under weather conditions that are not optimal for sun drying, the drying capacity of the dryer seems to be lower than what has been the goal of the project. The test of September-October 2001 showed a longer drying period and a lower drying capacity due to high humidity of the ambient air was high. Still, the weather conditions were not extreme for this time of the year in Ghana, and therefore, the dryer should also be applicable for that kind of conditions. Further tests are, however, necessary in order to determine the drying capability under less fortunate conditions. For further detailes on the performed tests on the solar crop dryer please refer to (Jensen et al, 2002).

The cost of the solar crop dryer (five units) has for Ghanaian conditions been estimated to be $13,625 without VAT by the beginning of 2002. This is too high a cost in order to be profitable if the solar dryer only is used for drying of maize for seed as the dryer only will be in operation during a small part of the year. In order to be profitable a much longer running time is necessary (Jensen, Kristensen and Forman, 2001).

The solar crop dryer may, however, also be used for drying of other crops. This will enlarge the total number of operational days per year and thereby improve the economy of the dryer. Preliminary tests at Silwood Farms (Jensen et al, 2002) have shown that the dryer very well dry e.g. cassava, pepper and okro within 3 days. Thus, there are good possibilities for drying

of other crops, but the drying methods and the construction of the drying bed have to be developed for these alternative crops.

However, although very enthusiastic about the solar crop dryer the manager at Silwood Farms has not performed many drying tests on his own. The solar crop dryer has been utilized lees than expected. It is, therefore, difficult to determine the economical benefit of the solar crop dryer. More tests and experience from daily use of the solar crop dryer all the year round for a larger variety of crops is necessary before it will be possible to determine the economics for the solar crop dryer.

The tests have revealed that the solar crop dryer performs more or less as expected. However, the tests have also revealed certain areas where the solar crop dryer may further be improved.

Further development and tests on the solar crop dryer are thus important in order to maximize the performance, experience and economical benefit of solar crop drying. It is, however, judged that the results of the present project makes a good basis for a future commercial break through of solar crop drying

Based on the tests of the solar crop dryer the Ghanaian consultant concludes (Jensen et al, 2002):

- In analyzing the economic viability of the solar dryers, the focus should be on the return on investment (profit) and the quality of the product as a result of utilizing the system.

- These are critical points to consider since open sun drying is favourable competitor, which has proven efficient in the drying of food items both on subsistence and commercial scale. However an improvement on the solar crop dryer will give it an advantage, since it is a cleaner technology.

- A consumer preference survey (to ascertain the social acceptability) effective marketing campaign (through demonstrations) and the active involvement of the private sector are some important factors to consider in the economic evaluation process.

- Unfortunately a credible decision on the economic viability of the solar dryers cannot be deduced based on the findings of the project sited on Silwood Farms at Pokuase in Accra, because information gathered is insufficient. In addition to that, information on solar dryers in Ghana is rather scanty/lacking. More demonstration farms may have to be sited on selected farms throughout the country in order to provide a credible statistical evaluation on its economical viability.

- It may be concluded that the technology is still at its teething stage in the country and such promotional programmes /projects should be consistent and intensified.

7.2. Solar fish dryer

Base on the survey, the Danish experts concluded*: "The survey showed that there is a need for improved methods for drying of fish. However, if the fish is lifted up from the ground on a net (instead of being dried on the ground) this will increase the quality of the dried fish so much that drying in a solar dryer would not add further value to the fish.*

It is, therefore, proposed to leave the demonstration plant for drying of fish out of the project and instead concentrate more on the two other types of solar dryers in order to increase the possibility of success here."

However, the Energi Commission strongly felt the necessity of testing a solar fish dryer. It was, therefore, decided to test one unit of the solar crop dryer as solar fish dryer.

The first trials were performed at Elite Enterprise Ltd. at Tema. This experiment failed because the owner of Elite Enterprise Ltd. although agreed to test the system wasn't interested in the project and declined to perform any experiment on her own. The main reason for this was that the owner of Elite Enterprise Ltd. although explicitly explained the purpose and size of the project had expected a larger facility capable of drying a larger part of the production of the firm. DENG Ltd., therefore, took over the responsibility of performing tests. However, due to the location – 35 km from Accra (and the premises of DENG Ltd.) - the tests were difficult to perform. These first trials showed longer drying time and poorer quality than traditional sun drying. A more detailed description and interviews with the owner and workers at Elite Enterprise Ltd. may be found in (Jensen et al, 2002).

The solar fish dryer was, therefore, transferred to the premises of DENG Ltd. where the Ghanaian consultant performed additional tests. These tests revealed that the solar fish dryer satisfactory dried smaller species of fish resulting in a good quality while larger species needed long time in the dryer. The capacity of the dryer was found to be a problem – i.e. too low capacity as the fish should be dried in one layer only. More detailed description of the tests and the test results may be found in (Jensen et al, 2002).

The Ghanaian consultant conclude based on a larger survey that drying of fish in solar dryers is a feasible and viable technology, however, the actual design tested in the present project should be modified and improved considerably in order to be of interest for commercialization.

7.3. Solar wood dryers

Two solar wood dryers were erected at Clipper Design Ltd. in Monkoadze: a forced open-air dryer and a solar kiln.

7.3.1. Forced open-air dryer

The concept of the open-air dryer was designed based on the available climate data for Ghana – e.g. summarised in (Jensen, 2001). These date state a relative high ambient humidity – most of the time above 60 % - which makes this concept interesting. However, the relative humidity turned at Monkoadze often out to drop below 20 %. This resulted for the performed trials in shell drying, development of stress and of major cracks in the wood. After three trials is was, therefore, decided to drop the concept and turn the forced open-air dryer into a solar kiln.

The forced open-air wood dryer may, however, still be interesting under other more humid climatic conditions.

7.3.1. Solar kiln

The solar kiln is basically identical to traditional kiln in its function except that the solar kiln operate at a daily cycle with highest temperature and air speed in the kiln during the day with solar radiation while having a lower temperature level and air speed during the night. Especially the low air speed during the night is traditionally considered a problem as it is assumed that a certain high air speed is necessary in order to avoid growth of e.g. fungus on the wood. However, the experience by Clipper Design Ltd. is that the daily cycle is beneficial as the rest period during the night allows the water inside the wood to travel to the surface and in this way avoid shell drying of the wood.

Several trials have been performed with the (by the end) two solar kilns in order to learn how to operate the kilns and in order to maximise the performance of the kilns with respect to drying time and wood quality. During the first trials the wood was not dried as hard as possible, however, as it turned out that the quality of the wood was impressively good the wood was gradually dried harder and harder resulting in lower drying time. Smaller changes were further gradually introduced to the solar kilns in order to enhance the performance of the kilns. For a detailed description of the test results please refer to (Jensen et al, 2002).

By the end of the test phase tests at Clipper Design Ltd. showed that it was possible to dry the wood faster and with a higher quality (i.e. less waste) than in a traditional kiln. The number of tests and further tests on only one location don't make it possible with scientifically significance to state if the solar kiln performs better than traditional kilns. However, the test results encourage to further explore the possibility of the solar kiln.

The owner of Clipper Design Ltd. is very happy about the solar kilns as they considerably have speeded up the drying time of the wood and further reduced the waste of wood. He can thus highly recommend the used of this type of kilns and has further gained much experience on the running of the kilns, which he may hand on to others who wish to obtain their own solar kilns.

The cost of the 10 m^3 solar kiln is in Ghana calculated to be approx. $14.500 incl. VAT by the beginning of 2002. It has not been possible to obtain the initial cost of a traditional kiln of 10 m^3, however, the cost of larger kilns indicates that a traditional kiln will be more expensive than the solar kiln in this small size. The running cost of the solar kiln is further lower than the running cost of a traditional kiln – mainly due to the electricity to the fan.

Based on the tests of the solar kilns the Ghanaian consultant concludes (Jensen et al, 2002):

- It is strongly recommended that the many useful lessons learnt from this project be put to use by supporting the duplication of the solar kilns at strategic locations.

- In addition to this, massive education would be necessary on the nature of wood, wood-water relations and the drying and handling of wood generally. This will be particularly useful for small- and medium scale wood workers.

- Already, the Timber Industry Development Division of the Forestry Commission, under the E.U-sponsored Wood Sector Development Programme, is offering assistance to the industry to improve wood drying in Ghana. Any future activities in solar drying of wood could be linked to this on-going effort.

8. Conclusions and recommendations

Four solar dryers where developed and erected in Ghana: a solar crop dryer, a solar fish dryer and two solar wood dryers. The dryers have been tested and much experience has been gained. In the following the dryers are listed in order of success.

8.1. Solar wood dryers

8.1.1. Solar kiln

The solar kiln shows remarkable results indication that this type of wood dryer may even be superior to conventional kiln with respect to drying time, quality of the wood and economy.

It is, therefore, recommended that the work on this type of solar wood dryer is continued. Solar kilns should be erected at strategic location through out Ghana in order to gain experience from different climatic locations and different types of companies. Especially it is recommended to locate a solar kiln at the forest research institute FORIG in Kumasi as Kumasi is the "wood town" of Ghana and because FORIC may use the solar kiln for further research and help to disseminate the technology. Courses on running the kilns should be set up in order to teach the people who are going to operate the kilns how to run the kilns and how to handle wood properly. Future work on solar kilns should be linked to ongoing research and development programs in the wood sector.

8.1.2. Forced open-air dryer

The forced open-air dryer turned at the chosen location out to be of little benefit. However, this type of dryers may be interesting at more humid locations and should thus not be abandoned completely.

8.2. Solar crop dryer

The solar crop dryer performed close to expected and shows potential for becoming economically profitable. However, more experience on the day to day use of the dryer year round is necessary in order to pinpoint the economics for this type of dryer. In case of (as expected) good results the work on the solar crop dryer should continue. The dryer should based on the gained experience be further developed.

Solar crop dryers should after the above be erected at strategic location through out Ghana in order to gain experience from different climatic locations and different types of crops. Courses on running the solar crop dryers should further be set up in order to teach the people who are going to operate the dryers how to run the dryers and how to handle the crops properly. Future work on solar crop dryers should be linked to ongoing research and development programs in the agricultural sector.

8.3. Solar fish dryer

The tested concept for a solar fish dryer turned out to be of only little benefit. It is thus not recommendable to continue tests and perform future development on the actual solar fish dryer.

It has together with the Energy Commission of Ghana been decided to transfer the solar fish dryer to the Solar Laboratory at the Department of Mechanical Engineering, University of Science and Technology Kumasi where it may be used for research and education in the field of solar drying.

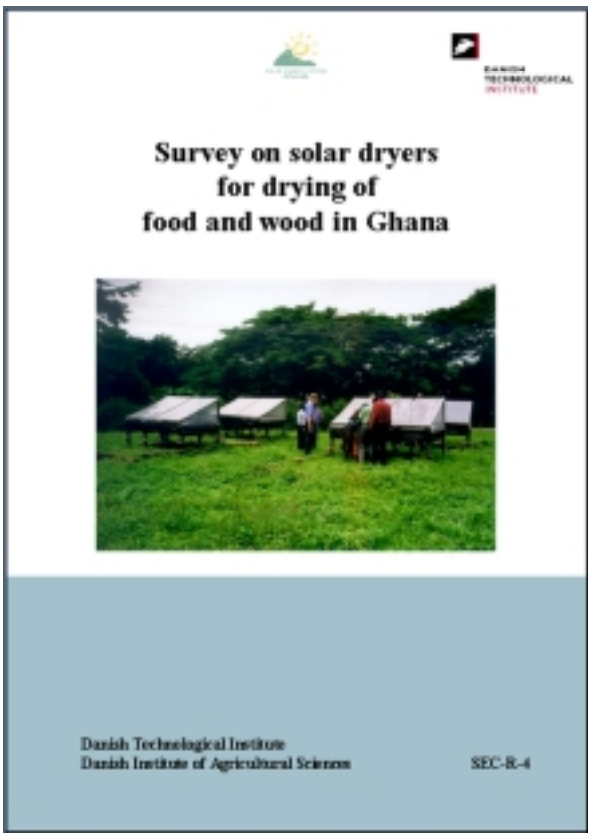
8.4. General considerations

It is judged that the project has been very successful as much experience and new knowledge has been gained and documented – mainly on the solar kiln and the solar crop dryer. However, work still has to be done in the field of further development, documentation of the performance and economical benefit and education before the technology gets commerzially mature so a massive dissemination of the technology may be launched.

It is believed that solar drying in the future may be part of the solutions, which may bring progress to the development countries.

9. Reports from the project (and references for the report)

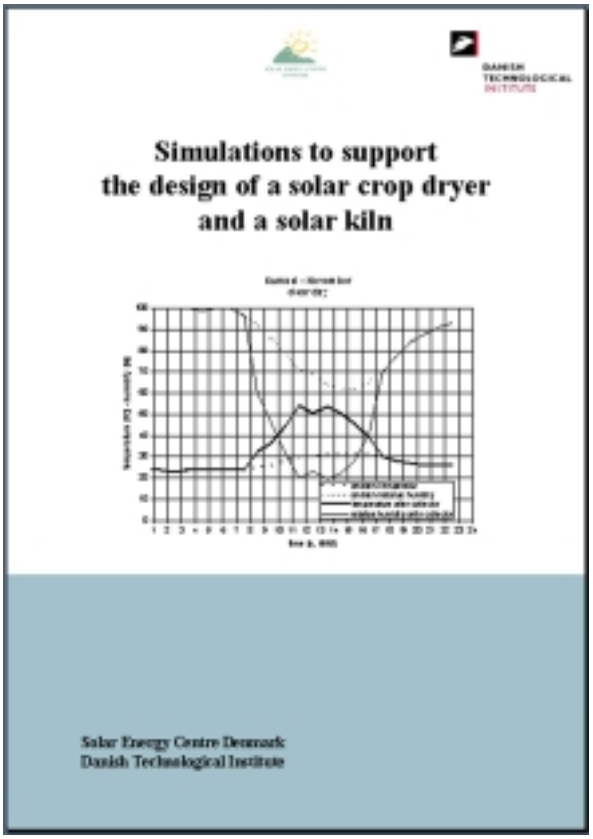
The present chapters contain references to the reports produced in the project.



Jensen, S.Ø., Frank, F.C. and Kristensen, E.F., 1999. *Survey on solar dryers for drying of food and wood in Ghana*. Solar Energy Centre Denmark and Wood Technology, Danish Technological Institute and Department of Agricultural Engineering, Danish Institute of Agricultural Sciences. ISBN 87-7756-583-5.

The report may directly be downloaded from: www.risoe.dk/solenergi/rapporter/sec-r-4.htm.

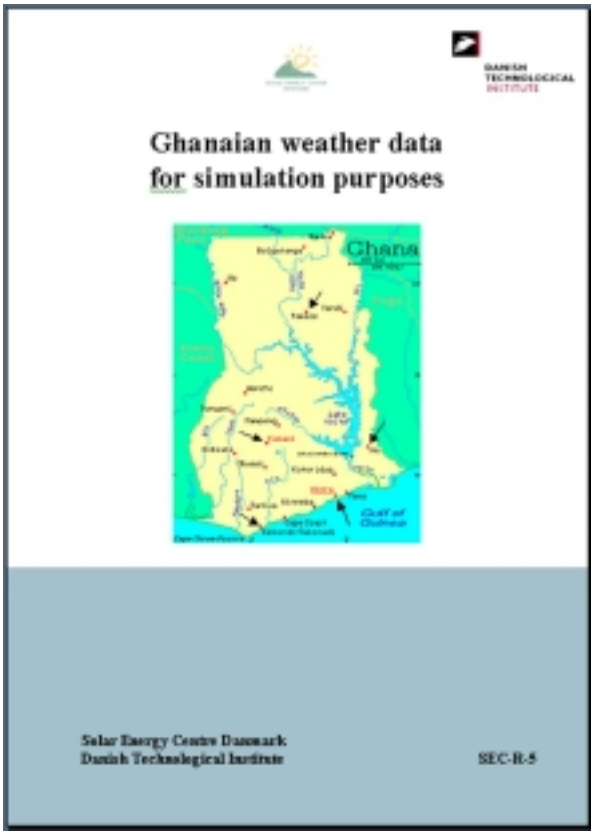
The report contains the findings from a visit to Ghana by the Danish partners at the start of the project.



Jensen, S.Ø., 2000. *Simulations to support the design of a solar crop dryer and a solar kiln*. Solar Energy Centre Denmark, Danish Technological Institute.

The report may directly be downloaded from: http://www.buildvision.dk/pdf/simulations.pdf

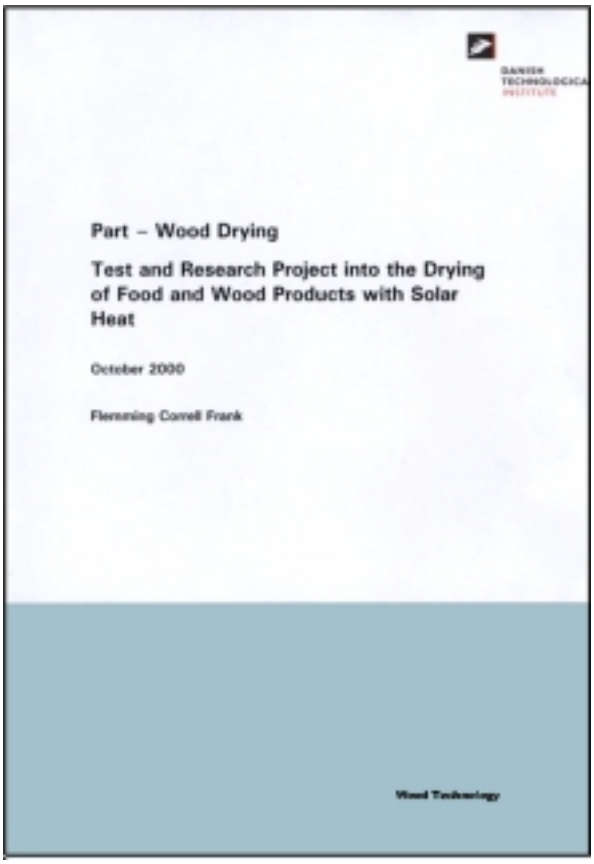
The report contains the results from simulation of temperature and humidity conditions in a solar crop dryer and a solar kiln based on the weather data given in the below report.



Jensen. S.Ø., 2001. *Ghanaian weather data for simulation purposes*. Solar Energy Centre Denmark, Danish Technological Institute. ISBN 87-7756-582-7.

The report may directly be downloaded from: www.risoe.dk/solenergi/rapporter/sec-r-5.htm

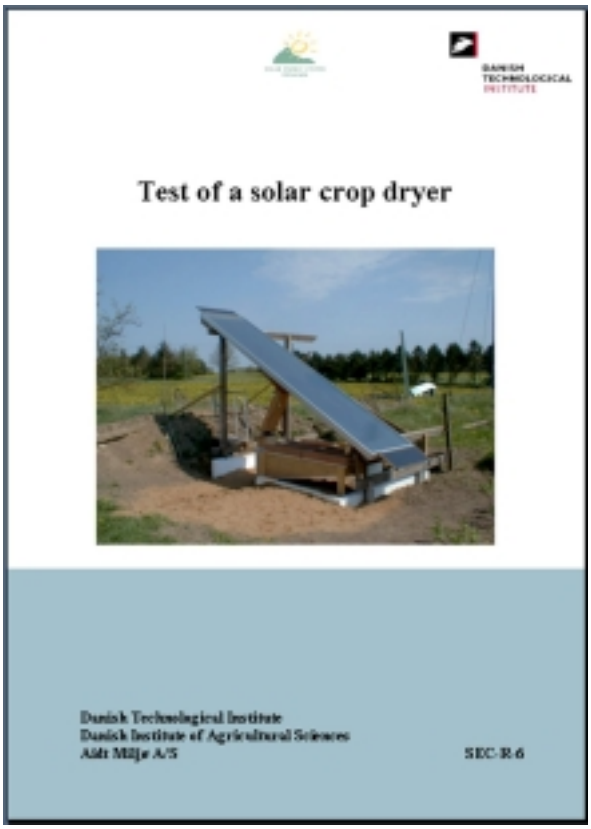
The report contains weather data for simulation purposes for 6 locations in Ghana: Accra, Ho, Kumasi, Sefwi-Bekwai, Takoradi and Tamale. The weather data is available as mean monthly hourly values for global radiation, horizontal diffuse radiation, dry bulb temperature, relative humidity and wind speed 2 m above the ground.



Frank, F.C., 2000. *Test and Research Project into the Drying of Food and Wood Products with Solar Heat – Part: Wood Drying*. Wood Technology, Danish Technological Institute.

The report may directly be downloaded from: http://www.buildvision.dk/pdf/part_wood_drying.pdf

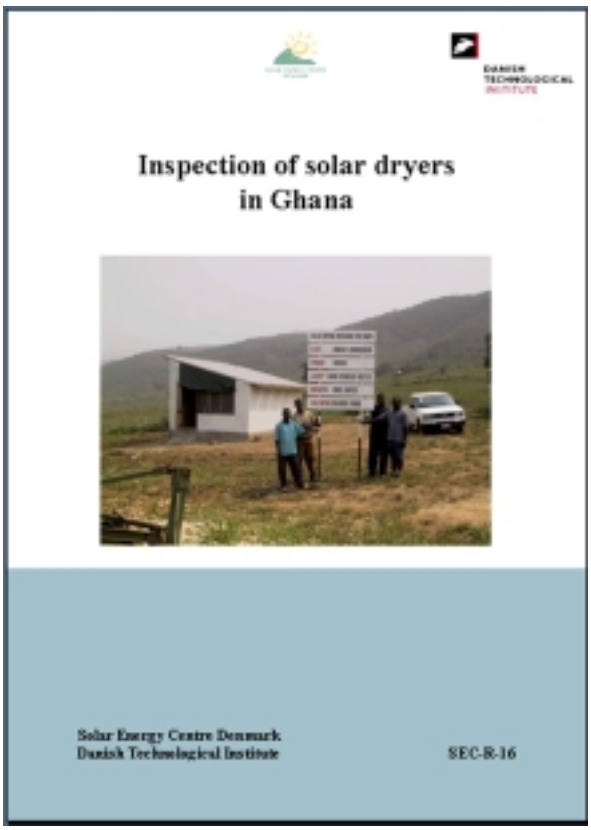
The report deals with the development of a forced open-air solar dryer for drying of wood.



Jensen, S.Ø., Kristensen, E.F. and Forman, T., 2001. *Test of a solar crop dryer*. Solar Energy Centre Denmark, Danish Technological Institute, Department of Agricultural Engineering, Danish Institute of Agricultural Sciences and Aidt Miljø A/S. ISBN 87-7756-583-5.

The report may directly be downloaded from: www.risoe.dk/solenergi/rapporter/sec-r-6.htm.

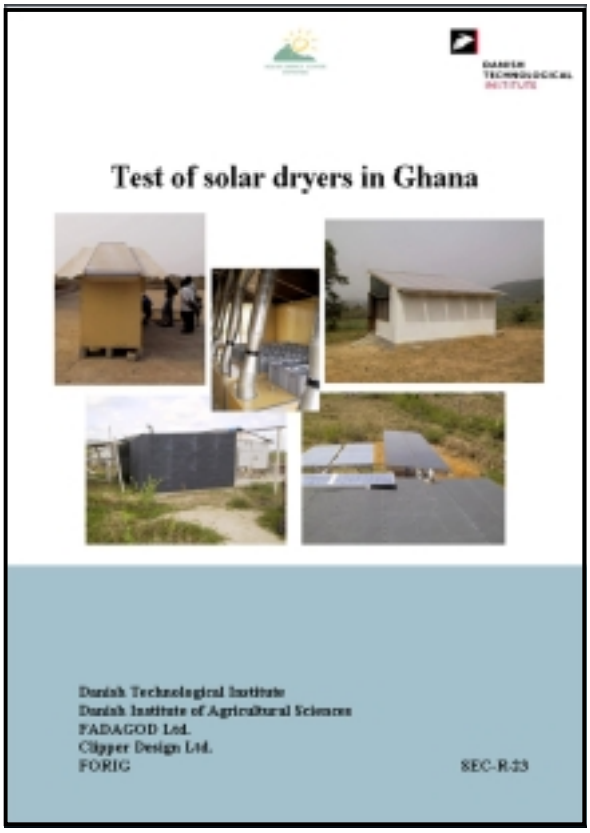
The report describes the development of the solar crop dryer and the results from the tests carried out on the solar crop dryer in Denmark.



Jensen. S.Ø., 2001. *Inspection of solar dryers in Ghana*. Solar Energy Centre Denmark, Danish Technological Institute. ISBN 87-7756-615-7.

The report may directly be downloaded from: www.risoe.dk/solenergi/rapporter/sec-r-16.htm

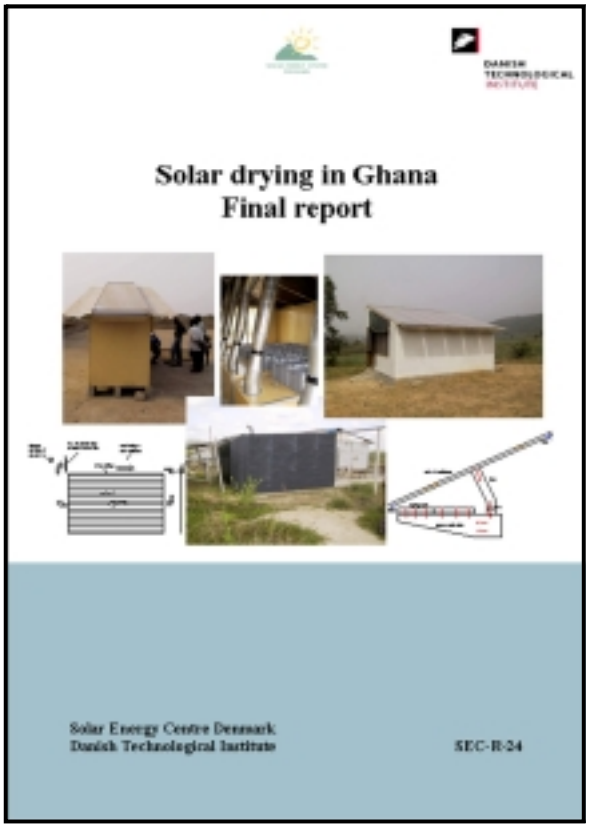
The report contains the findings including test results from a visit by the co-ordinator of the project to the three solar dryers erected in Ghana as part of the project. The visit was carried out in January 2001 right after the dryers were erected and tests had to begun.



Jensen, S.Ø., Kristensen, E.F., Agyei, F.G, Larsen, T. and Nketia, K.S.., 2002. *Test of solar dryers in Ghana*. Solar Energy Centre Denmark, Danish Technological Institute, Department of Agricultural Engineering, Danish Institute of Agricultural Sciences, FADAGOD Ltd., Clipper Design Ltd. and FORIG. ISBN 87-7756-658-0

The report may directly be downloaded from:
www.risoe.dk/solenergi/rapporter/sec-r-23.htm

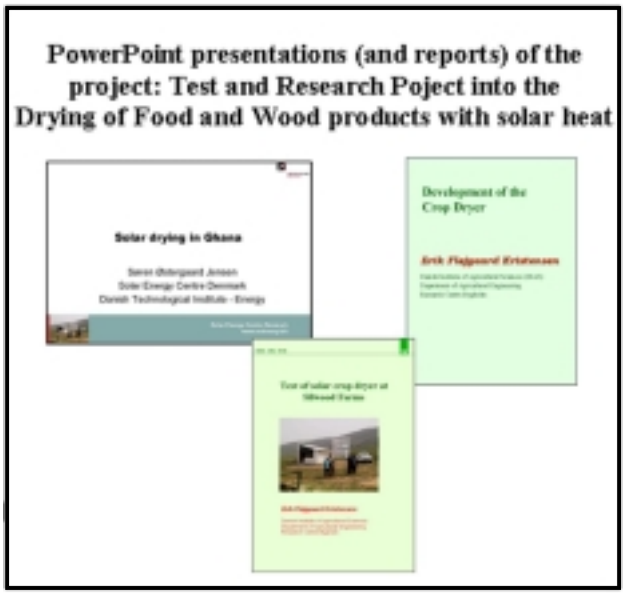
The report contains the findings and results from the tests carried out in Ghana on the solar crop dryer, the solar fish dryer and the solar wood dryers.



Jensen, S.Ø., 2002. *Solar drying in Ghana – Final report*. Solar Energy Centre Denmark, Danish Technological Institute. ISBN 87-7756-659-9

The report may directly be downloaded from:
www.risoe.dk/solenergi./rapporter/sec-r-24.htm

The report finalizes the project: Test and research project into the drying of food and wood products with solar heat.



CD-ROM with three PowerPoint presentations of the project: one overall presentation of the whole project, one presentation of the development of the solar crop dryer carried out in Denmark and one presentation of results from test of the solar crop dryer in Ghana.

The CD-ROM further contains the reports from the project in pdf format.

Annex A

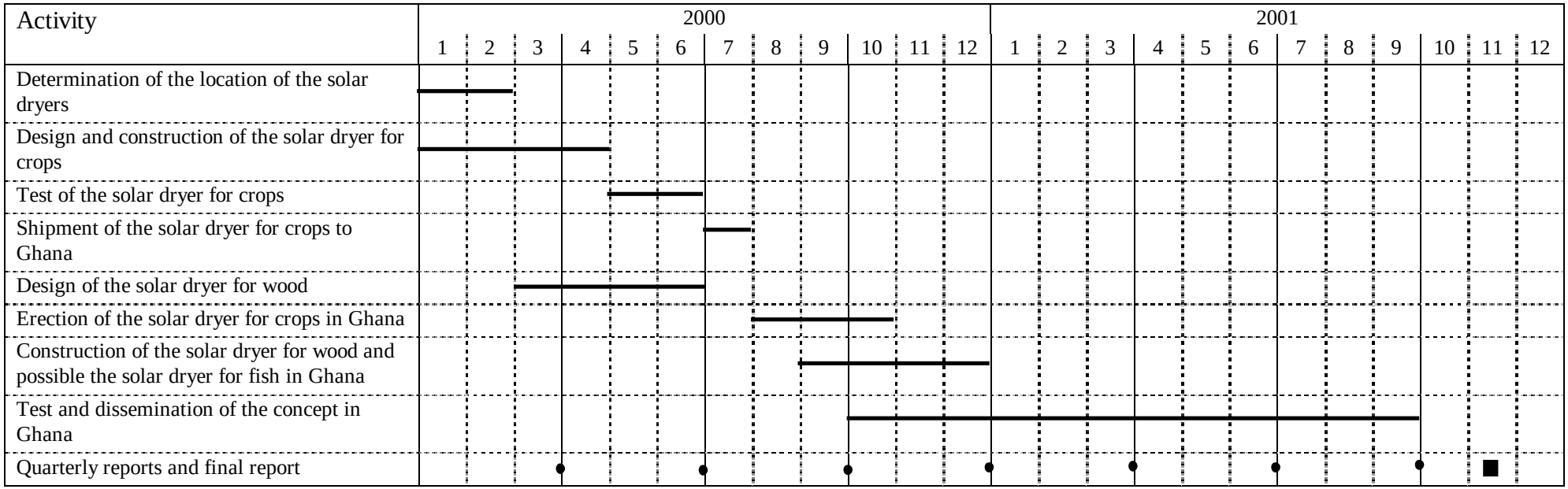
Implementation plan

Procedure and time schedule - application

Activity	year 1												year 2											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Collection of information on climate, crops, wood and fish in Ghana																								
Drying process for crops																								
Drying process for wood																								
Drying process for fish																								
Dimensioning of solar heating system																								
Building of the first test unit in Denmark																								
Test and optimization of the first test unit																								
Shipment of the test unit to Ghana																								
Building of two test units in Ghana																								
Test and dissemination of the concept in Ghana																								

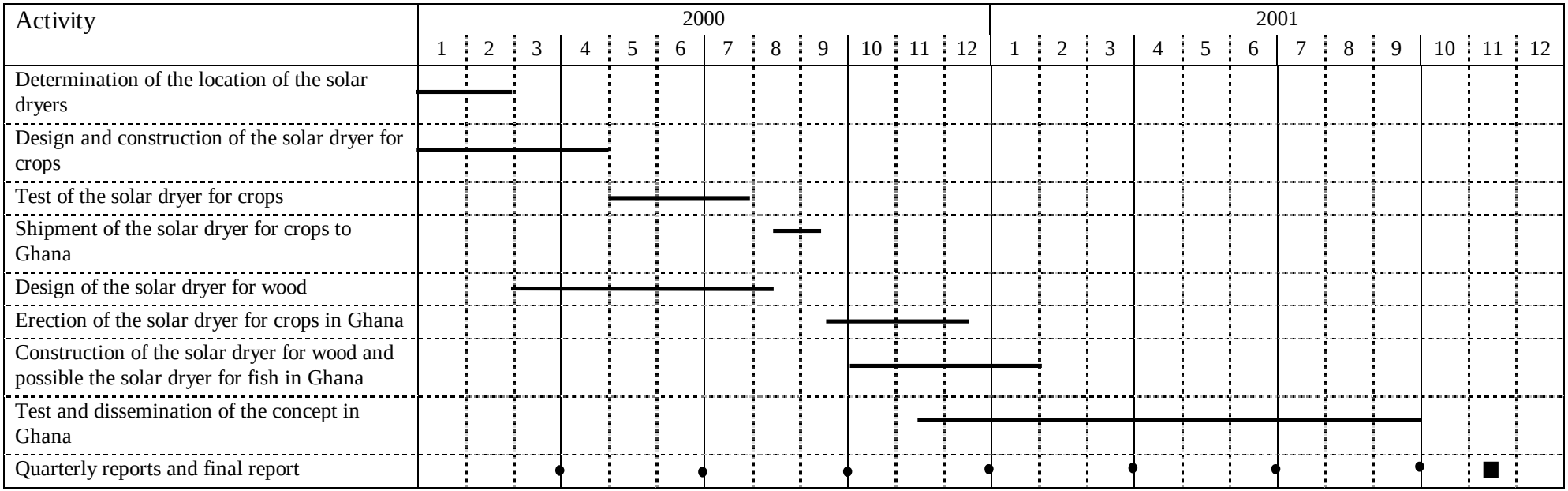
Implementation plan

Revised Time Schedule – December 20, 1999



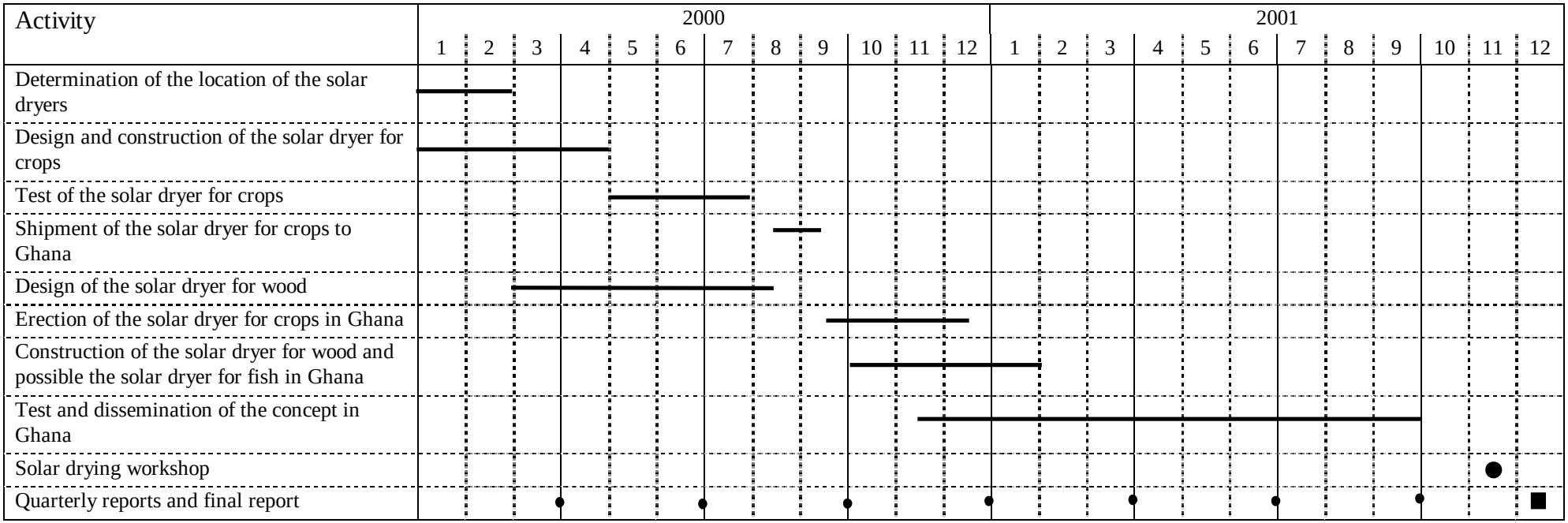
Implementation plan

Revised Time Schedule – June, 2000

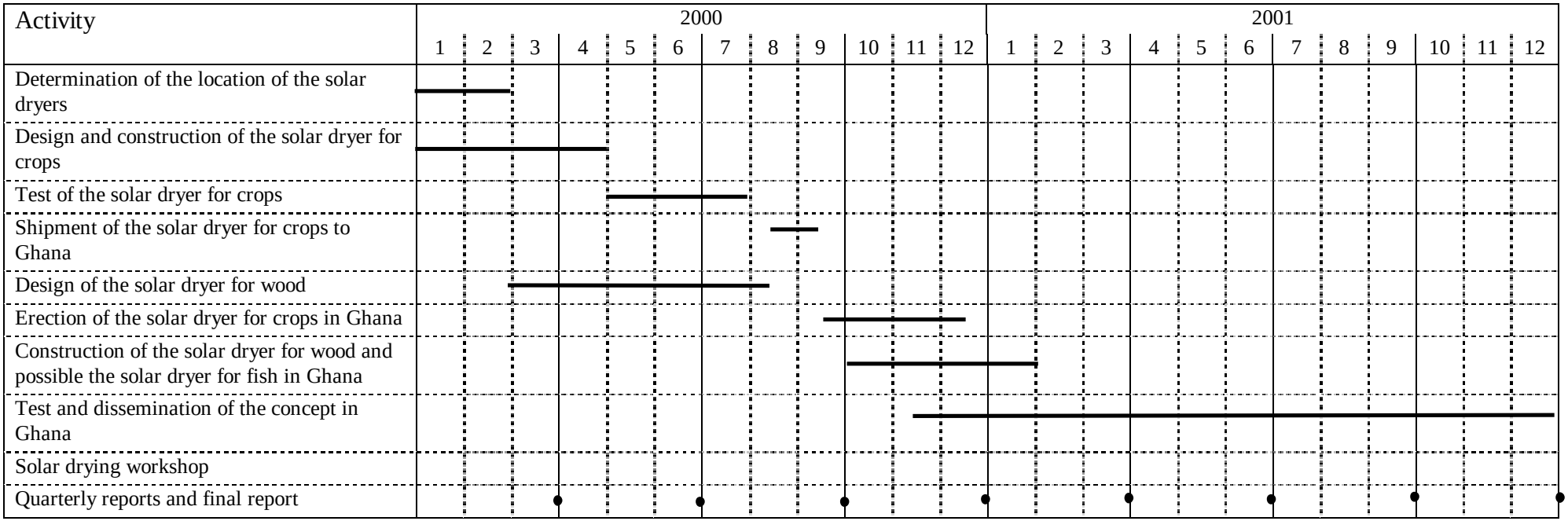


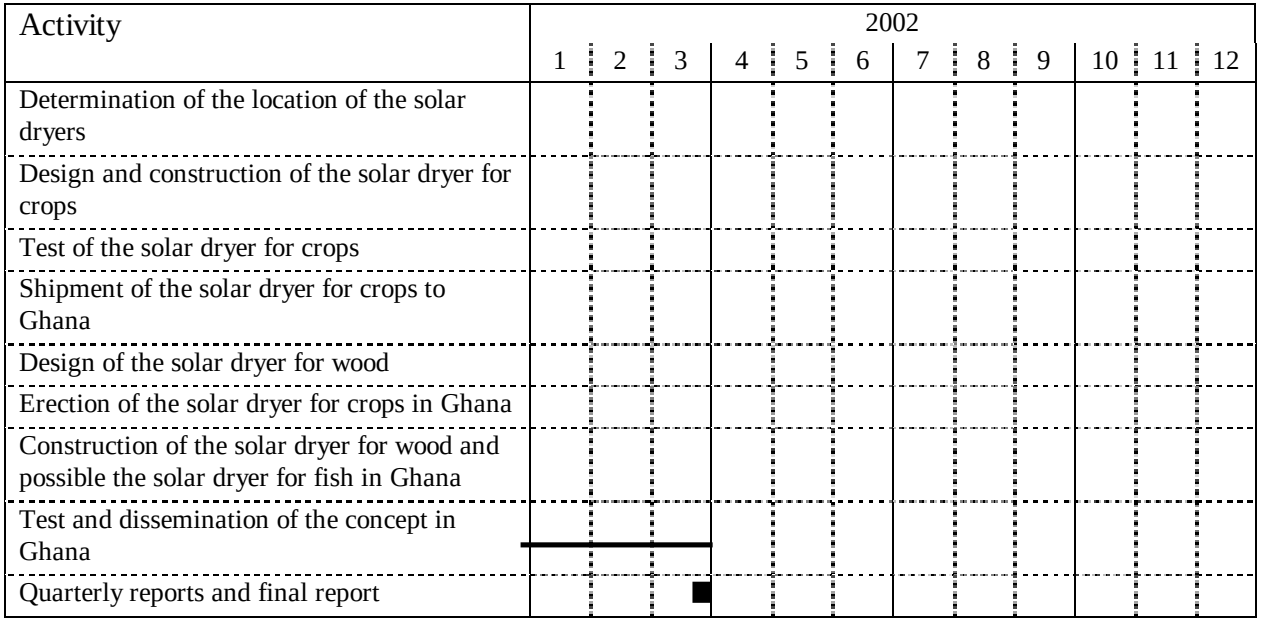
Implementation plan

Revised Time Schedule – October, 2001



Implementation plan: Revised Time Schedule – December, 2001





Annex B

Progress reports for the Danish partners of the project

Progress Report: January 1st - March 31st, 2000 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the project for this period - see the implementation plan in the annex - was:

1: to determine the locations for the solar dryer for crops and for the solar kiln
2: to design the solar crop dryer and start the construction of the test prototype
3: to start the design of the solar kiln

1: The locations for the solar crop dryer and for solar kiln have been approved:

The solar crop dryer will be located at: Silwood Farms at Pokuase
The solar kiln will be located at: Clipper Design at Mankoadze

Silwood Farms has a total land area of 210 acres of which 176 acres are used for maize cultivation while the rest is used for growing pineapples. Silwood Farms dry maize for seeds. Silwood farms employs about 10 people. The owner is very interested in the project as this will reduce the use of kerosene which he currently uses for drying the maize. The company is prepared to contribute by paying for using the dryer. Other farmers may also use the dryer.

Clipper Design is a small carpenter firm mainly manufacturing doors. The firm employ 1-3 people besides the owner. The owner is very interested in the project as he find it difficult to obtain dried wood in a proper quality. The company is prepared to invest own time in making the solar kiln operational and in running tests with the solar kiln.

2: The design of the test prototype has been approved based on calculation on drying conditions and performance of the solar air collector and investigations on suitable materials and components. A modulized concept has been chosen. Each units consist of:

- Collector: Outer dimensions: 4900 x 1070 mm². Transparent area: 4.89 m². Cover: Double walled ribbed UV-stabilized polycarbonate. Absorber: Black felt mat. Air intake at the back in both ends and air outlet in the middle at the back.
- Solar cell panel: 12 V, 14 W.
- Fan: 300 m³/h at 40 Pa. 12 V dc motor.
- Duct between collector and drying bed: Diameter = 200 mm.
- Drying bed: 3 trays of 850 x 530 mm² = 1.35 m².
- Regulation: Thermostatic damper

The capacity of the unit will be 100 kg maize. The demonstration plant in Ghana will consist of 5 units: capacity = 500 kg maize, collector area ≈ 25 m². In Ghana the collectors will form the roof of the building containing the drying beds.

A modulized concept has several benefits: If one drying bed is operated improperly this will not affect the total quantity of crops being dried at that time. It is possible to start with only one unit and then gradually increase the capacity of the solar dryer - this will make it easier to invest in a solar dryer.

One unit of the solar dryer is under construction. It is expected that the unit will be operational by mid April.

For further details on the design process and design please refer to the enclosed progress reports from Aidt Miljø, the Danish Institute of Agricultural Sciences, Department of Agricultural Engineering and Solar Energy Centre Denmark in the annex.

3: The first 3 moths of 2000 has mainly been used to collect knowledge and investigate different materials for the solar kiln.

Tasks for the period April 1st - June 30th

Solar crop dryer: Denmark: Construction and test for the prototype test unit. Modification of the concept based on the test results if necessary. Shipment of the prototype to Ghana.

Ghana: Construction of the building carrying the solar air collectors and containing the drying beds of the prototype solar crop dryer.

Solar kiln: Final design and instruction on how to build the solar kiln.

Progress Report: April 1st - June 30th, 2000 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the project for this period - see the implementation plan in Annex A - was:

1: to test the solar crop dryer
2: based on 1 to modify the design of the solar crop dryer if necessary
3: ship the solar crop dryer to Ghana
4: to design the solar kiln
5: find a location for the fish dryer

1-2: The first design of the solar crop dryer was erected in April. Based on measurements on the dryer carried out by Solar Energy Centre Denmark, the Danish Institute of Agricultural Sciences and Aidt Miljø the design of the dryer was modified in order to allow for a higher air flow rate through the dryer. The results from the tests and the modifications made on the dryer are thoroughly documented in the report "Test of a solar crop dryer" which is available in a draft version.

The final design of the solar crop dryer includes five units with the following components:

- Collector: Outer dimensions: 4900 x 1070 mm². Transparent area: 4.77 m². Cover: Double walled ribbed UV-stabilized polycarbonate. Absorber: Black felt mat. Air intake at both ends of the collector and air outlet in the middle at the back of the collector.
- Solar cell panel: 2 panels: 12 V, 14 W_p.
- Fan: 300 m³/h at 40 Pa. 12 V dc motor.
- Duct between collector and drying bed: Smoothed metal ductworks.
- Drying bed: 6 trays of 558 x 358 m² (internal dimensions) = 1.2 m² with a height of 262 mm.
- Regulation: High air speed so that regulation due to high temperatures isn't necessary

Concerning regulation: It is necessary to maintain a high air flow rate in the dryer in order to avoid too high temperatures to the drying bed. The tests have shown that due to a non-perfect match between the characteristic of the fans and the pv-panels the air flow may get too low under Ghanaian conditions with high ambient temperatures. This may be solved using a maximum power point tracker in between the fans and the pv-panels - this is investigated at the moment. It is further possible to add thermal mass in the pressure chamber of the dryers as this will smoothen the temperature of the air to the drying bed.

The solar air collectors, the ductworks and the drying beds for the demonstration plant have been produced. The construction of the support structure for the solar crop dryer has begun in Ghana.

3: The solar crop dryer should according to the implementation plan have been shipped by the end of June. The shipment has, however, been postponed as material from Denmark

for the solar kiln are going to be shipped in the same container as the solar crop dryer. The design of the solar kiln is by the end of June not finalized - see the next section.

4: The main problem in designing a solar kiln turned out to be the necessary fan power for circulation of the air in the kiln. A high air speed rate through the woodpile is necessary in order to prevent attacks from mould and fungi during the drying process. Furthermore, the air speed has to be increased if more heat is injected from solar air collectors to the kiln. For a small 10 m³ kiln the necessary power of the fan is above 3 kW which is expensive to obtain by pv.

At the moment two proposals for the design of the solar kiln has been presented:

A: Forced open-air drying
B: Hybrid drying with re-circulation of the drying air

The two proposals and the considerations behind them are described in Annex B.

The main difference between the two concepts is that due to injection of heated air from solar air collectors design B needs a control system and more fan power than design A.

The decision on which design to chose will be made at a meeting on July 17, 2000 with participant from the involved partners:

Wood Technology, Danish Technological Institute:	Flemming Correll Frank and Christian Boye.
DENG:	Frede Bosteen and Niels Jepsen
Aidt Miljø:	Torkil Forman
Solar Energy Centre Denmark, Danish Technological Institute:	Søren Østergaard Jensen

Due to the holiday season and the Ghanaian participants it was not possible to have an earlier meeting. This does unfortunately postpone the design of the solar kiln with 1½ months as seen in Annex A showing the revised timetable from December 1999 and the new timetable. However, it is at the moment estimated that this will not effect the date of the finalization of the project.

5: DENG has together with K.A Otu-Danquah pointed out a location for the fish dryer. The fish dryer will consist of one unit similar to the five units of the solar crop dryer. The dryer is recommended to be erected at Elite Enterprise Limited, Tema for the following reasons:

- The company dries anchovies and fish waste in commercial quantities throughout the year.
- The owner of the company has shown interest in the technology of the plant and readiness to contribute towards the project with regard to paying for using the plant to dry his products.
- The site is accessible and close to Accra to ensure easy monitoring.

Tasks for the period July 1st - September 30th

Solar crop dryer: Denmark: Finalize the tests and the test report. Ship the dryer to Ghana.

Ghana: Finalize the construction carrying the solar air collectors and containing the drying beds of the prototype solar crop dryer. Start the erection of the solar crop dryer.

Solar kiln: Denmark: Together with DENG agree on the design of the solar kiln. Finalize the design and instruction on how to build the solar kiln.

Ghana: Prepare the erection of the solar kiln.

Fish dryer: Denmark: Bits and pieces will be shipped together with the crop dryer.

Ghana: Start the erection of the fish dryer.

Documents included the progress report

Final version of the report "Survey on solar dryers for drying of food and wood in Ghana" including comments from Professor Akufo.

Draft version of the report "Ghanaian weather data for simulation purposes" awaiting comments from Professor Akufo.

Draft version of the report "Test of a solar crop dryer" awaiting the results for the last tests.

Drawings showing the two proposed designs for a solar kiln.

The working document "Simulations to support the design of a solar crop dryer and a solar kiln".

Progress Report: July 1st - September 30th. 2000 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the project for this period - see the implementation plan in Annex A - was:

1: to finalize tests on the solar crop dryer
2: to ship the solar crop dryer to Ghana
3: to start the erection of the solar crop dryer
4: to finalize the design of the solar kiln
5: to prepare the erection of the solar kiln
6: to prepare the erection of the fish dryer

1: More tests than foreseen were carried out on the solar crop dryer in Denmark. The effect of a maximum power point tracker (mppt) on the solar panels and the effect of thermal mass in the pressure chamber below the drying bed were also tested. The reason for the mppt was to increase the air flow through the system at high PV cell temperatures and the reason for increased thermal mass was to decrease the risk of too high temperatures which may damage the seed.

The extra tests in Denmark have not postponed the shipment of the solar dryer for Ghana but have increased the knowledge on the performance of the solar crop dryer.

The report on the performed tests is now in a final draft version and will be distibuted for comments.

The development of a simple measuring procedure for tests of the dryer in Ghana has started. Further the development of a measuring system for more detailed tests on the dryer has also started. This latter tests will be carried out in January 2001 - in the secondary maize season.

2: The solar crop dryer and materials for the fish dryers were shipped at the beginning of August. The container was received by DENG by the end of September - a bit later than foreseen in the implementation plan

3: The erection of the solar crop dryer in Ghana has stated. Torkil Forman from Aidt Miljø went to Ghana on September 27 and will stay in Ghana for a fortnight to assist DENG with the erection of the dryer.

4: The design of the solar kiln has been more difficult than foreseen. A meeting was held in Denmark on July 17 with participants from Wood Technology, Aidt Miljø, DENG and Solar Energy Centre Denmark - the minutes from the meeting is enclosed as appendix B.

The former progress report described two different approaches for a solar wood dryer in Ghana: a forced open-air-dryer and hybrid drying with re-circulation of the drying air. On the meeting it was decided to go for a forced open-air-dryer because of the difficulties and price of a hybrid drying with re-circulation of the drying air.

However, when going back to Ghana DENG found out that Clipper Design was not interested in a forced open-air-dryer. The argument is that this type of dryer will not add much more value to the wood than the existing drying method. Clipper Design has in coperation with Niels Jepsen (DENG) proposed a new design for a closed solar kiln. However, the wood experts cannot recommend the design as the risk of damaging the wood due to the difficulties in controlling the temperature, humidity and air speed is to high.

The problems has increased after that as it has been difficult to obtain a real dialog between the Ghanaian partners and Wood Technology. The dialog has gone through the project leader Søren Østergaard Jensen instead of directly among the directly involved persons - the latter would most properly have speeded up the process. Wood Technology has been too determined on carrying out the decisions from the meetings on July 17 and has not paid much attention to the signals from Ghana.

Wood Technology will finalize their work on the decided forced open-air-dryer by October 5. The report on their work including drawings and a report on the investigation on a low cost dc driven fan will be circulated among the participants.

After that it is necessary to come to a consensus on the design of the dryer. The problem is that Clipper Design and Wood Technology seems very firm on which design to chose - unfortunately the preferred design is very different. Clipper design want a more advanced dryer in order to speed up the drying process and reduce that moisture content of the wood. Wood Technology are very worried about the quality of the wood as sever damaged based on their experience most properly will occur to the wood leading to much more waste of wood than today.

Torkil Forman, Aidt Miljø has by the end of September carried out some measurements at Clipper Design which support the arguments from Clipper Design - that the drying conditions today at Clipper Design is close to what will be obtained in a forced open-air-dryer. This has to be considered when defining the design of the dryer.

5: The foundation for the dryer is ready. The erection of the dryer will be postponed due to the above difficulties which first have to be solved.

6: The erection of the fish dryer will start by mid October. The design of the fish dryer will basically be as the crop dryer.

Tasks for the period October 1st - December 31st

Solar crop dryer: Denmark: Collect and incorporate comments on the test report. Develop a simple measuring procedure for test of the dryer (ongoing). Develop a measuring system for more detailed test of the dryer (ongoing). This latter test will be carried out in January 2001 - in the smaller maize season.

Ghana: Erect the solar crop dryer. Carry out an report on simple tests on the dryer.

Solar kiln:	Denmark: Finalize the design and drawings for a forced open-air-dryer. Together with the Ghanaian partners decide on the design.
	Ghana: Together with the Danish partners decide on the design. Erect the dryer.
Fish dryer:	Ghana: Erect the fish dryer.

Documents included the progress report

Draft version of the report "Test of a solar crop dryer".

Final report from Wood Technology including drawings of a forced open-air-dryer.

The report "Testing of 24 VDC Ventilator"

Progress Report: October 1st - December 31th, 2000 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the Danish work in the project for this period (the work of the Ghanaian partners will be reported by DENG) - see also the implementation plan in Annex A - was:

1: to finalize the report on the tests carried out on the solar crop dryer in Denmark
2: to help DENG with the erection of the solar crop dryer
3: to develop a simple test procedure for the solar crop dryer
4: to develop a measuring system for the solar crop dryer
5: to finalize the report on the forced open-air wood dryer
6: together with the Ghanaian partners to decide on the design of the wood dryer
7: it was further the aim of DENG to erect the solar fish dryer

1: It was decided to include a chapter in the report on the economy of the solar crop dryer under Ghanaian conditions. DENG has collected the required data and will soon transfer them to the Danish partners. The Danish Institute of Agricultural Sciences will then perform the economical calculations. The finalization of the report is, thus, postponed.

2: Torkil Forman form Aidt Miljø went to Ghana on September 27, 2000 and helped DENG for a fortnight with the erection of the solar crop dryer at Silkwood Farms. The dryer is now in operation.

3: Erik Fløjgaard Kristensen, the Danish Institute of Agricultural Sciences has developed a simple test method for the solar crop dryer. The method is included in the progress report as Annex B.

4: Søren Østergaard Jensen, the Solar Energy Centre Denmark has developed a simple measuring system for continuos measurements on the solar crop dryer based on Tinytag dataloggers. The measuring system will be installed in week 4 of 2001 where Søren Østergaard Jensen will visit Ghana.

5: The report including drawings on the open-air wood dryer was finalized in October 2000 and circulated together with the previous progress report.

6: A solution for the wood dryer has been reached. Thanks to DENG two types of dryers will be erected at Clipper Design, Mankoadze:
- one open-air dryer based on the recommendation by Wood Technology and
- one closed version designed by DENG and Clipper Design where control of the humidity and temperature level will be possible.

It is expected that two different dryers considerable will increase the outcome from this part of the project. The erection of the two dryers is expected to be finalized by mid January 2001

7: The erection of the fish dryer at Elite Enterprise Limited, Tema has been finalized. The dryer will son be ready for operation.

Prior to the here reported period the project was a bit behind schedule. However, the project is now back on schedule as seen in the implementation plan in Annex A.

Tasks for the period January 1st - March 31st for the Danish partners

The Danish co-ordinator (Søren Østergaard Jensen) of the project will visit Ghana during the period January 22-27. Søren Østergaard Jensen will visit the three sites with solar dryers and have meetings with the Ghanaian partners. Søren Østergaard Jensen will report on the findings from the visit.

Solar crop dryer: Denmark: Start-up of the measurements on the solar crop dryer together with DENG and Silkwood Farms

Ghana: Continue the measurements and tests on the solar crop dryer.

Solar kiln: Ghana: Finalize the dryers. Perform experiments with the dryers.

Fish dryer: Ghana: Perform experiments with the dryers

Document included the progress report

Test of solar crop dryer in Ghana

Progress Report: January 1 - March 31, 2001 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the Danish work in the project for this period (the work of the Ghanaian partners will be reported by DENG) - see also the implementation plan in Annex A - was:

1: visit of the co-ordinator Søren Østergaard Jensen to the three solar dryers in Ghana
2: agree on tests and procedure for reporting of the results from the tests on the three dryers
3: start up of the tests in the three dryers – especially the detailed measurements and the simple test procedure on the solar crop dryer
4: prepare a chapter on economy for the report "Test of a solar crop dryer"

1: Søren Østergaard Jensen visited Ghana during the period January 22-27, 2001. The findings from the inspection on the three dryers are fully documented in the report "Inspection of solar dryers in Ghana". A draft of the report was circulated for comments in February 2001. The final version of the report is released together with this progress report

2: The plans for the testing and reporting on the tests on the three dryer has been described in the report "Inspection of the solar dryers in Ghana" and been agreed on by the approval of the report by the other participants in the project. Please refer to the above-mentioned report for details on the testing and reporting.

3: Detailed measurements on the solar crop dryer have been started – the first weeks of measurements are documented in "Inspection of the solar dryers in Ghana". DENG has in March mailed one month of measurements to Solar Energy Centre Denmark who has processed the measured data.

The simple test method described in the former progress report has been implemented at Silwood. The first filled in table from Silwood have been received by Solar Energy Centre Denmark and passed on the Department of Agricultural Engineering, Danish Institute of Agricultural Sciences for evaluation

4: A chapter on economy for the report "Test of a solar crop dryer" has been drafted by the Department of Agricultural Engineering, Danish Institute of Agricultural Sciences and will soon be put into the report. The final version of the report will then be prepared and circulated.

The report from the initial survey visit of the Danish experts in October 1999 "Survey on solar dryers for drying of food and wood in Ghana" is now available on the internet on the following address: www.risoe.dk/solenergi/rapporter/sec-r-4.htm.

The project is on schedule as seen in the implementation plan - Annex A.

Tasks for the period April 1 - June 30 for the Danish partners

Assist the Ghanaian partners in the tests of the solar dryers – especially the tests on the solar crop dryer.

Progress Report: April 1 - June 30, 2001 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the Danish work in the project for this period (the work of the Ghanaian partners will be reported by DENG) - see also the implementation plan in Annex A - was:

1: finalize the report describing the visit of the co-ordinator Søren Østergaard Jensen to the three solar dryers in Ghana
2: finalize the report on the tests carried out in Denmark on the prototype crop dryer.
3: help the Ghanaian partners with the interpretation of the measuring data from the solar crop dryer at Silwood Farms

1: The final version of the visit report was finalized by the beginning of April 2001 and was released together with the former progress report. The report is now also available via the internet on www.risoe.dk/solenergi/rapporter/sec-r-16.htm.

2: The missing chapter on economy for the report describing the test carried out in Denmark on the prototype crop dryer has been finalized. The report has been released and is included this progress report. The report is now also available via the internet on www.risoe.dk/solenergi/rapporter/sec-r-6.htm.

3: Data has been collected for the maize drying season in January. Unfortunately the harvest was poor this year - far less maize than normal was harvested. For this reason only a few measuring series are available. The evaluation of the measured data is described in the document "Test of solar crop dryer at Silwood Farms", which is enclosed this progress report.

The project is on schedule as seen in the implementation plan - Annex A. The tasks of the Danish partners have only been minor during the last three month. The main work during this period has been carried out by the Ghanaian partners - please refer to the progress report from DENG.

Tasks for the period June 1 - August 31 for the Danish partners

Assist the Ghanaian partners in interpreting the measured data from the solar crop dryer during the main maize season - August-September.

It is planned to have a seminar in Ghana on solar drying by the end of the project in November 2001 in order to help the dissemination of the results from the project. The Danish partners will assist the Ghanaian partners in preparing this seminar,

Progress Report: July - September 30, 2001 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the Danish work in the project for this period (the work of the Ghanaian partners will be reported by DENG) - see also the implementation plan in Annex A - was:

1: help DENG in organizing the Solr Drying Workshop
2: evaluate drying data from the solar crop dryer at Silwood Farms

1: The workshop has been organized and the agenda will be circulated very soon. The workshop will take place on November 7 and will be hosted by DENG

2: Data from Silwood Farms has just by the beginning og October begun to be available. The evaluation of data from the main maize harvest season will hopefully be completed for presentation at the workshop

The project is on schedule as seen in the implementation plan - Annex A. The tasks of the Danish partners have only been minor during the last three month.

Tasks for the period October - December 31 for the Danish partners

Evaluate the measurements carried out at Silwood Farms.

Participate in the Solar Drying workshop in Ghana on November 7. Participate in the presentation of the construction of the three dryers and the results from the performed measurements.

Collect the results from the measurements and user experience on the three dryers and publish this as an report.

Together with DENG prepare the final report of the project.

Finalize the project.

Progress Report: October 1 - December 31, 2001 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the Danish work in the project for this period (the work of the Ghanaian partners will be reported by DENG) - see also the implementation plan in Annex A - was:

1: participate in the Solar Drying Workshop
2: evaluate drying data from the solar crop dryer at Silwood Farms
3: collect the results from the measurements and user experience on the three dryers and publish this as an report.
4: together with DENG prepare the final report of the project.
5: finalize the project.

1: The Energy Commission of Ghana postponed the workshop as they felt that the work of the Ghanaian consultants was not advanced enough to make a workshop beneficial. No decision has as yet been made on if or when to have the workshop

2: Data from Silwood Farms for the period September 17-October 13 has been evaluated. Unfortunately the precision of the measurements was too poor. No conclusions could be made based on the measurements - a document describing the evaluation is enclosed the progress report (Test of solar crop dryer at Silwod Farms, September - October 2001). An new test was performed during the period November 9-11, where the water content of the maize before and after the drying was determined by the Food Research Institute of Ghana. However, this test was nor conclusive. Erik Fløjgaard Kristensen has, therefore, written a new step by step procedure in order to facilitate better measurements - also enclosed.

3: Solar crop dryer: The report on the performance of the solar crop dryer is being written. The results from the performed tests have been evaluated and described. However, more precise measurements are necessary in order to conclude on the performance of the solar crop dryer. The consultant Ms. Florence Agyei, FADAGOD Co. Ltd has prepared a first draft of her report on the solar crop dryer

Solar fish dryer: A report on the performance of the solar fish dryer has been prepared by the consultant Ms. Florence Agyei, FADAGOD Co. Ltd.

Solar kilns: A test report on the solar kilns is in the process of being prepared by Tonny Larsen, Clipper Design Ltd. The consultant K.S. Nketia, Forest Research Institute will prepare an evaluation report on the solar kilns.

The task of preparing a report on the measurements and experience on the three solar dryers is behind schedule as only one sub-report is in its final state.

4: Solar Energy Centre Denmark has prepared a proposal for the final report. The final report can, however, not be finalized before the tasks under 3) have been finalized.

5: The projects has not been finalized due to the reasons mentioned under 3) and 4).

The project is no longer on schedule as seen in the implementation plan - Annex A. The implementation plan has, therefore, to be altered. It is proposed to postpone the final report to the end of the first quarter of 2002 as seen in Annex B. The change in the implementation plan will give more time to collect and edit the results and experience from the tests carried out on the three solar dryers in Ghana.

Tasks for the period January 1 - March 31, 2002 for the Danish partners

Perform and evaluate a more precise test carried out at Silwood Farms.

Collect the results from the measurements and user experience on the three dryers and publish this as an report.

Together with DENG prepare the final report of the project.

Finalize the project. It is at the moment being investigated if it is possible to find funding for a visit to Ghana by the Danish co-ordinator in order to formally finalize the project.

Tasks for the period January 1 - March 31, 2002 for the Ghanian partners

Perform economical calculations on the three solar dryers under Ghanain conditions,

Solar crop dryer: Perform a new test. Ms. Florence Agyei should finalize her evaluation report on the solar crop dryer.

Solar kilns: Clipper Design should finalize their test report on the solar kilns. The consultant K.S. Nketah should finalize his evaluation report on the solar kilns.

DENG and the consultants should assist the Danish partners in finalizing the report on the measurements carried out in Ghana and the final report of the project.

Progress Report: January 1 - March 31, 2002 for the project Test and Research Project into the Drying of Food and Wood Products with Solar Heat

The aim of the Danish work in the project for this period (the work of the Ghanaian partners will be reported by DENG) - see also the implementation plan in Annex A - was:

1: visit to Ghana by the co-ordinator Søren Østergaard Jensen and Erik Fløjgaard Kristensen
2: meetings with the Energy Commission, the Danish Embassy, the Ghanaian consultants, University of Kumasi and FORIG
3: perform and evaluate a more precise test carried out at Silwood Farms
4: collect the results from the measurements and user experience on the three dryers and publish this as an report
5: prepare the final report of the project
6: finalize the project.

1: The co-ordinator Søren Østergaard Jensen and Erik Fløjgaard Kristensen visited Ghana during week 10 (March 3-8), 2002

2: Two meetings with the Energy Commission were arranged during the visit of Søren Østergaard Jensen and Erik Fløjgaard Kristensen. On the first meeting March 4 the progress of the project and the program for the visit were discussed. On the last meeting Søren Østergaard Jensen and Erik Fløjgaard Kristensen gave PowerPoint presentations on the outcome of the project including the latest findings obtained during the visit. The project was discussed and several important decisions were taken: that the crop and wood dryers should remain at the hosts, however, with full access for the Energy Commission. It was concluded that the solar fish dryer wasn't feasible for the purpose. It was decided that the solar fish dryer should be transferred to the University of Science and Technology Kumasi to the Solar Laboratory of the Department of Mechanical Engineering. The possibility of erecting two new dryers – one for crops and one for wood – near Kumasi was discussed – however, no final decision was reached.

The Danish embassy was informed on a meeting on the progress and outcome of the project. A representative from the Embassy was further present at the final meeting at the Energy Commission.

The expectations for the evaluation reports were discussed and agreed with the Ghanaian consultants Florence Agyei and K.S. Nketiah.

The Department of Mechanical Engineering, University of Science and Technology (UST) Kumasi and FORIG was visited on March 7, 2002 in order to investigate future possibilities for solar drying in Ghana. It was determined that both UST and FORIG would benefit from obtaining a solar dryer, which they could utilize for research and demonstration purposes and in this was help to disseminate the technology.

3: Erik Fløjgaard Kristensen performed a very precise drying experiment at the solar crop dryer at Silwood Farms. The results have evaluated and included into the

4: Main part of the report “Test of solar dryers in Ghana” has been collected into a report. Still remaining contributions: an evaluation report on the solar crop dryer and the solar wood dryers by the Ghanaian consultants.

5: Main part of the final report has been written. The last part of the report await the finalization of the measuring report under 4).

6: The finalization of the project awaits the finalization of 4) and 5). The finalization has been discussed with the Energy Commission

It is hoped that the remaining reports will be finalized during April, 2002 and that the draft of the final report may be circulated for comments by the end of April, 2002.

Remaining tasks for the Danish partners

Finalize the report on the measurements performed in Ghana.

Finalize the final report.

Finalize the project.

Remaining tasks for the Ghanian partners

Ms. Florence Agyei should finalize her evaluation report on the solar crop dryer.

Mr. K.S. Nketiah should finalize his evaluation report on the solar wood dryers.

DENG and the consultants should assist the Danish partners in finalizing the report on the measurements carried out in Ghana and the final report of the project.

The Ghanaian partners should comment on the final report and the report on the measurements carried out in Ghana.

Annex C

Progress reports for the Ghanaian partners of the project

DENG
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April 13th, 2000

Energy Commission
Diamond House
Accra

Attention: The Executive Director, Dr. T.W. Ansah

Re: Solar Drying Project
Report as at 21st March 2000

The first quarter of the year concentration was on the final selection of the location sites for the solar crops dryer and the solar kiln dryer.

End of January 2000 the Consultant Mr. Otu-Danquah and the undersigned traveled to a proposed site at Fufuo near Barkese north of Kumasi, a distance of 370 km from Accra where we inspected crop growers storage facilities of maize and spoke to a few farmers. We realized, however, that the site was too remote and without proper management, and in fact did not meet any of the criteria established for this pilot project.

Our search continued with visits to Silwood Farms which is located between Accra and Nsawam, it has a land of over 210 Acres. Silwood Farms dry maize for seed, which is one of the main criteria for selection. It employs about 10 people, and is managed by Mr. Frank Abu-Korang Amoako, an agronomist who appears a serious and competent Farm Manager, and he has assured us of his full co-operation. – Participants in two visits to the farm were Mr. Otu-Danquah, Mrs. Lydia Kwasetu from Ministry of Food and Agriculture, Seed Certification Division and others. At a second visit, the General Manager of DENG Ltd, Mr. Asamani Osae and our Solar Engineer Consultant, Niels Jepsen also participated.

Since Silwood Farms met with all the criteria as set out in a minute from DTI dated December 20th 1999, the farm was recommended for the site for the Solar crops dryer.

As regards the Solar kiln dryer, in their visit report, the DTI Consultants has already pointed to clipper Design at Mankoadze near Winneba as a suitable location, and with no apparent objection from the local consultant it was decided to recommend Clipper Design for selection as it also meets all criteria set out in the aforementioned minute.

Clipper Design is managed by Mr. T. L. Larsen, a Danish carpenter, it employs 2 – 3 people in addition to Tony Larsen. He is very interested in the project and is prepared to invest his own time in making the solar drying kiln operational and in running tests.

Reference is also made to the Consultants reports already submitted to you and to DTI end of March report.

Our recommendations to select respectively Silwood Farms as the location for the Solar Crops Dryer, and Clipper Design for the Solar Kiln Dryer have been approved by E.C.

During the quarter, DENG accepted to co-ordinate future activities of the Consultants.

A co-ordination meeting will take place in Denmark on 2nd May between DTI, its partners and DENG to evaluate progress so far. – DENG has requested information in respect of the foundations for the dryers so this work could commence and be completed in good time.

Yours faithfully,
For: DENG Limited

F. B. Bøsteen

Encl. Photographs from Silwood Farms.
DTI Report
Consultants Reports

c DTI, HO, NSS.

DENG Limited
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FAX TRANSMISSION ADVISE

TO: Energy Commission FAX NO.: 660718

ATTENTION: Dr. T.W.Ansah, Executive Secretary DATE: 30.06.2000

FROM: F.B.Bosteen NO. OF PAGES: 1

Re: Solar Drying Project-Report as at 30th June, 2000

1. Solar Crops Dryer: A meeting was called at Aidt Miljø, Denmark on 2nd May, 2000 at which Deng was represented by F.B.Bosteen.-All members of the DTI project group attended. The project leader Søren Ø.Jensen, chaired the meeting.-An erected prototype of the Solar Crops Dryer was inspected, it was performing well, and will be ready for shipment to Ghana in knock-down form in July.
   Drawings for the foundation and walls have been received by Deng, and the construction work has been started up at Silwood Farms with expected completion in July.
   When the container with the drying equipment has arrived, Mr. Torkil Forman of Aidt Miljø Denmark, will visit Ghana to supervise the erection of- and starting up of the Crops Dryer in collaboration with Deng staff led by Niels Jepsen.
   Photographs of the prototype have been sent to you already.

2. Solar Kiln: Progress has been made concerning the design of the Solar Kiln, but some technical discussions are still going on in order to reach a final solution.- The undersigned took part in a hearing at DTI on 15th June, 2000 and pressed for a conclusion.- A final technical meeting will take place at DTI on 17th July, 2000 where all members of the DTI Group of consultants will be present, and DENG will be represented by F.B.Bosteen and Niels Jepsen(on leave).- After this meeting it is expected that the design, already well advanced, can be finalised so the project can progress as planned.

3. Solar Fish Dryer: Co-ordination continued with the Local Consultants Econkoad, who finally identified a suitable site for the erection of a small Solar fish dryer. The location is at Elitet Enterprise Limited, owned by Mrs. Elizabeth Tetteh, about 5km on the other side of Tema, along the coast.-The place was visited by F.B.Bosteen and Niels Jepsen of Deng together with the local consultant Mr. Otu-Danquah. - The recommendation by the consultant was endorsed by Deng since it meets the criteria of the project. Reference is also made to the detailed report by the local consultant which was submitted to Energy Commission on 1st June, 2000.-Deng has delivered photographs from the site, and has confirmed the recommendation by e-mail to E.C. on 31.05.00 to which approval is awaited.

Yours faithfully

F.B.Bosteen

cc DTI

AFTER SALES SERVICE AVAILABLE

cc AO, KCe, NSS.

DENG
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Energy Commission
Diamond House,
Accra

3rd October, 2000.

Attention Dr. T.W.Ansah, Executive Secretary

Dear Sir,

Re: Solar Drying Project-Report as at 30th September, 2000.

1. Solar Crops Dryer:

   We are pleased to report that the construction of the foundations and the walls of the drying unit have been completed.-For more details concerning various follow-up inspection visits to the farm please see the attachments.

   The container with the drying equipment from Denmark was received on 26th September, and all the equipment has been transported to Silwood Farms. The engineer from Aidt Miljø Mr. Torkil Forman arrived on 27th September for a 2-week stay during which he will supervise the completion of the dryer and initial testing.

2. Fish Dryer: This was also received on 26th September. It will be assembled at DENG workshop and transported to the selected site at Tema where it will be erected within the next week.

3. Solar Kiln: The designing of this dryer has created some technical problems for the experts at DTI. Representatives of Deng Ltd took part in meetings at Aidt Miljø on 7th July, and at DTI on 17th July and 3rd of August however, without any conclusive results.- At the time of writing this report Deng Ltd is still waiting for drawings and instructions concerning the erection and completion of the wood dryer although several reminders have been sent.

   For further information on development progress of this dryer we have to refer to DTI.-

   In the meantime however, the concrete floor and foundation for the Solar Kiln have been completed by us.

4. The consultant on the Crops Dryer and Fish dryer presented his detailed invoice based upon completion of the tasks given to him, which was recommended for payment.

Yours faithfully
For: Deng Limited

F.B.Bosteen

Encl.

cc AO, NSJ, KKC

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Energy Commission
Diamond House
Accra

3rd January, 2001

Attention: Dr. T.W. Ansah, Executive Secretary

Dear Sir,

RE: Solar Drying Project – Report as at 31st December 2000

1. Solar Crops Dryer

At the beginning of October the main structure was completed, including the wooden part and all five air collectors installed to facilitate test runs.

On 7th October, an initial introduction was made to Energy Commission, DENG Management and Silwood Farms owner in the presence of Mr. Torkil Forman of Aidt Miljo, Denmark. Remaining work being carried out includes making of curtains to protect against rain, completion of roof sealed with silicone, fittings for the cover for air filters to activate the heat collector, painting and erection of sign boards.

2. Fish Dryer

All materials for the fabrication of the fish dryer were procured and the construction completed including the construction of fish dryer chamber, preparation of fish hangers, installation of net on windows, sealing of gap between panels and collectors, securing of collector to wooden structures, painting of structure with preservative, painting of structure with oil paint. The fish dryer has been transported to ELITET Enterprise, Tema where it has been erected and it is now ready for testing.

3. Solar Wood Dryer

The construction of the Solar Wood dryer went ahead based upon instructions received from DTI plus a locally modified version developed by DENG and Clipper Design. All the building materials, solar items and testing equipment have been procured and it is now estimated that the dryer will be completed by the middle of February 2001. The construction includes the manufacture of support structure for 30 modules, fixing of aluminum walls and roof, drying room installation, construction of fan boxes, and installation of fans.

Mr. Soren Ostergaard Jensen, project leader from DTI will visit Ghana from 21st to 27th January 2001, for an inspection of the three installations and to initiate the data collection and monitoring of the Crops Dryer. Both consultants have been informed of the impending visit.

Yours faithfully,
DENG Limited

F. B. Bosteen

encl.

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Our Ref. FBB/HKK

April 3, 2001

Energy Commission
Diamond House
Private Mail Bag
Ministries Post Office
Accra

Attn: Dr. T. W. Ansah
Executive Secretary

Dear Sir,

RE: SOLAR DRYING PROJECT – REPORT AS AT 31ST MARCH 2001

Mr. Soren O. Jensen, Project Leader from DTI, visited Ghana from 21st to 27th January 2001. –Inspection visit were made to all 3 dryers per the attached itinerary.

Attached are also reporting procedures as prepared by DTI, copies of which have been dispatched to all parties concerned including the consultants.

Solar Crop Dryer

DENG has in March mailed all measurements to Solar Energy Centre, Denmark at DTI who has processed the measured data. The first filled in table from Silwood Farms has also been sent to DTI.

The first testing of the Solar Crop Dryer was when the Energy Commission Board members visited the site on the 16/1/01. Maize was used as the test sample because it is the harvest period.

The team enquired of the drying efficiency of the system, to which the Farm manager, Mr. Frank gave the confirmation that results from maize, pawpaw and coconut are successful but pineapple has not given a good result.

However, on the arrival of Mr. Soren O. Jensen of DTI in the country, a visit to Silwood Farms on the 22/1/01 to monitor the system proved satisfactory. Other personnel who visited the farms were Mr. Asamani Osae, Mr. Bismarck Ampadu, Mr. N.K. Larbi (all of DENG Limited), and Mr. Otu-Danquah (a consultant of Energy Commission).

For proper monitoring, Mr. Jensen placed data-loggers (small yellow boxes) numbering seven at vantage points, to measure temperature, relative humidity, voltage and milli-volts etc. These data-loggers have been programmed monthly, so that they can be picked and loaded in a PC and the result sent to Denmark for assessment.

During his stay in Ghana, he monitored the system four times. He advised Mr. Frank to measure the rate of drying with the Grain Moisture Tester after the grains have cooled, in order to get a better result; since the drying start on the surface of the grain whereas the moisture content within has not been reached.

State Solar Wood Dryer

The Solar dryer is now in use with ten 80w panels to drive one large ventilator during the day. One 16" ventilator operates on battery during the night as well as a small 5W exhaust fan to take out moist air controlled by a hydrostat.

The Solar Dryer (accelerated Kiln) is operating perfectly with a controlled climate and temperature up to 40°C. The final position of the hydrostat and thermostat are yet to be determined.

The first batch of $4m^3$ ofram has been dried from above 35% down to an average of 17.5 in less than two weeks. This would have taken four to five weeks with normal outside air-drying. Hydrostat and thermostat have now been hooked up manually. Automatic timers are yet to be designed.

State of Forced Air Dryer

The forced air-drying kiln has not been used yet, because of RH% which ranges from 75% - 80% at midnight to 55 – 60% at 8.00 am and now in mid March down to 30% at noon.

The one period during February it even dropped below 10%. All these data have been collected on a calibrated mechanical hydrometer.

Solar Fish Dryer

Our solar engineer Mr. Bismarck Ampadu visited the fish dryer at Elite Enterprise, Tema on 23rd March and again on 27th March together with the consultant Mr. Otu-Danquah to monitor the performance of the dryer.

Information gathered there was that Tuna flakes were fed into the dryer on the 23rd March 01, at 10.00 am but at the time of visit, the sample was till not dry. Other works done were cleaning of the collector and filters beneath the PV panels.

Generally, it was observed that it takes 5 – 7 days to dry fish in the solar dryer. On the contrary, it takes about 2 days to dry fish in the open sun (outdoor). The only disadvantage is that when it rains the fish gets wet again.

Attached to this report is a map of the locations, photographs from Clipper Design Mankoadze and the implementation plan.

Yours faithfully,
For DENG Limited

F. B. Bosteen

Encls.

DENG
Engineering Services

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Our Ref. AO/HKK

29th May, 2001

Energy Commission
Diamond House
Private Mail Bag
Ministries Post Office
Accra

Attn: Dr. T. W. Ansah
Executive Secretary

Dear Sir,

RE: SOLAR DRYING PROJECT – REPORT AS AT 31ST MAY, 2001

Wood Dryers

On the 24th April, a delegation comprising Mr. Joseph Danquah from the Danish Embassy, Dr. T.W. Ansah of the Energy Commission and representatives of DENG Limited visited Clipper Design to acquaint themselves with the progress of work on the equipment. – At the time of the visit although the performance of the battery powering the fans was not good, the original dryer was yet to be completed and the second one was working to the satisfaction of the user. – Mr. Joseph Danquah from the Danish Embassy was happy with the performance of the system. This visit took the whole day.

On 27th April Deng's technical staff visited Clipper Design together with the consultant, Mr. Nketia. –During the visit a new and bigger battery was installed for the fan blowers and the panels, and the controllers were re-checked. Dimension for the gate for the forced air dryer was taken. – Subsequently an electric battery charger was built to boost the charging capacity of the battery at Clipper Design. This has helped the fans to run throughout the night. – Bismarck Ampadu has since visited the factory to collect data from the loggers.

Attached is a report from the Consultant, Mr. K.S. Nketia of FORIG, in which he makes some conclusions and recommendations. – A copy of Deng's response to this is also attached.

A budget covering the consultant's cost up to the closing of the Project in November has already been submitted to you together with Terms of Reference

Reports from the user continue to be positive.

Crops Dryer

On the 25th April 01, a delegation comprising Mr. Joseph Danquah from the Danish Embassy, Dr. T.W. Ansah of the Energy Commission, Deng's representatives visited Silwood Farms to inspect the Crops Dryer, and they were very happy about what they saw. There was drying of maize in progress and also the delegation was shown dried pineapple. – Maize production is seasonal and is out of season around this period.

In a separate letter to you we have recommended a new consultant for the project i.e. Ms. Florence G Agyei of CSIR, an Agricultural Scientist. Her CV has been provided together with a budget up to the end of the project in November.

Fish Dryer

The Solar Fish Dryer has been installed at Elite Enterprise Limited in Tema since December 2000. Two major tests have been carried out with products supplied by DENG Limited.

For very small fishes the system is able to dry them hygienically within 3 - 5 days depending upon the weather conditions. Although sun dried fish on the ground which is being practiced by the owner takes a much shorter time 2 - 3 days, it is not as hygienic as that of the new Solar Dryer.

The larger fish showed signs of getting rotten after 3 days.

This is well described by the co-ordinator in his write up February 2001, page 32.

Due to this phenomenon, the woman is not showing any interest in the system as such I suggest that the system is taken out and modified to suit crop drying just as that at Silwood Farms.

In our letter of May 28th , 01 we have proposed that the Fish Dryer is up-graded to another Crops Dryer similar to the one at Silwood Farms. – The proposed site i.e. Sunharvest Farms, which is located about 50m off Kasoa on the Winneba Road was visited during the latter part of May 2001, by Dr. T.W. Ansah of Energy Commission, Mrs. Gifty Mintah Darko and three representatives of Deng Limited including Mr. F. B. Bosteen. – The Farm has 100 acres, and 200 acres pineapple out growers with more land available mostly growing pineapples and some maize. – The company processing facility is near Accra.

A cost estimate of the up grading is attached for your approval since it will require an additional budget allocation.

Yours faithfully,
For DENG Limited

Asamani Osae

Encls.

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Our Ref. FBB/AO/HKK

October 4, 2001

The Executive Secretary
Energy Commission
Private Mail Bag
Ministries Post Office
Ministries, Accra

Dear Sir,

RE: SOLAR DRYING PROJECT
REPORT AS AT 30TH SEPTEMBER 2001

The monitoring of the dryers continued during the period 1st July to 30th September 2001 per the attached visit report. Both the Solar Crops Dryer and Solar Wood Dryer continue to function well.

Monitoring data have been forwarded as usual to DTI for analysis.

Forced Air Dryer: Approval was given by you to convert the Forced Air Dryer to another Solar Wood Dryer within DENG's approved budget. The job will be carried out during the first half of October.

Crops Dryer: A new Consultant has been approved by you to monitor its performance.

Fish Dryer: It has been collected from Tema and brought to DENG where it has been rehabilitated and where new tests will be carried out per the newly appointed consultant.

Closing of Project: DTI shall visit Ghana during week 45 starting 5th November 2001 when the project will close.

In this connection, one day Workshop shall be organized at DENG on 7th November. A copy of the programme is attached.

Yours faithfully,
For DENG Limited

Asamani Osae

Encs.

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Our Ref. AO/HKK

January 8, 2002

Energy Commission
Diamond House
Private Mail Bag
Ministries Post Office
Accra

Attn: Mr. Kofi Asante

Dear Sir,

Solar Drying Project as at 31st December 2001

Monitoring of the various dryers, Fish, Crop and Wood Dryers continued during the period 1st October to 31st December 2001 per attached visit report.

Data has also been sent to DTI for necessary analysis.

Solar Wood Dryer
As indicated in our previous report, the Forced Air Dryer has been converted into a Solar Wood Dryer. The performance as at now is satisfactory just like the previous one. Further test is being carried out.

Crops Dryer
The Consultant has carried out series of tests. These were done using different types of products. Report attached.

Fish Dryer
A Comprehensive test was carried out using different types of Fish. Report attached.

Yours faithfully,
For DENG Limited

Asamani Osae

Encls.