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Explanatory notes

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

References to dollars ($) are to United States dollars, unless otherwise stated.

The monetary unit in Jordan is the dinar (JD). During the period covered by the report, the value of the dinar in relation to the United States dollar was $US 1 = JD 0.313.

The following abbreviations are used in this report:

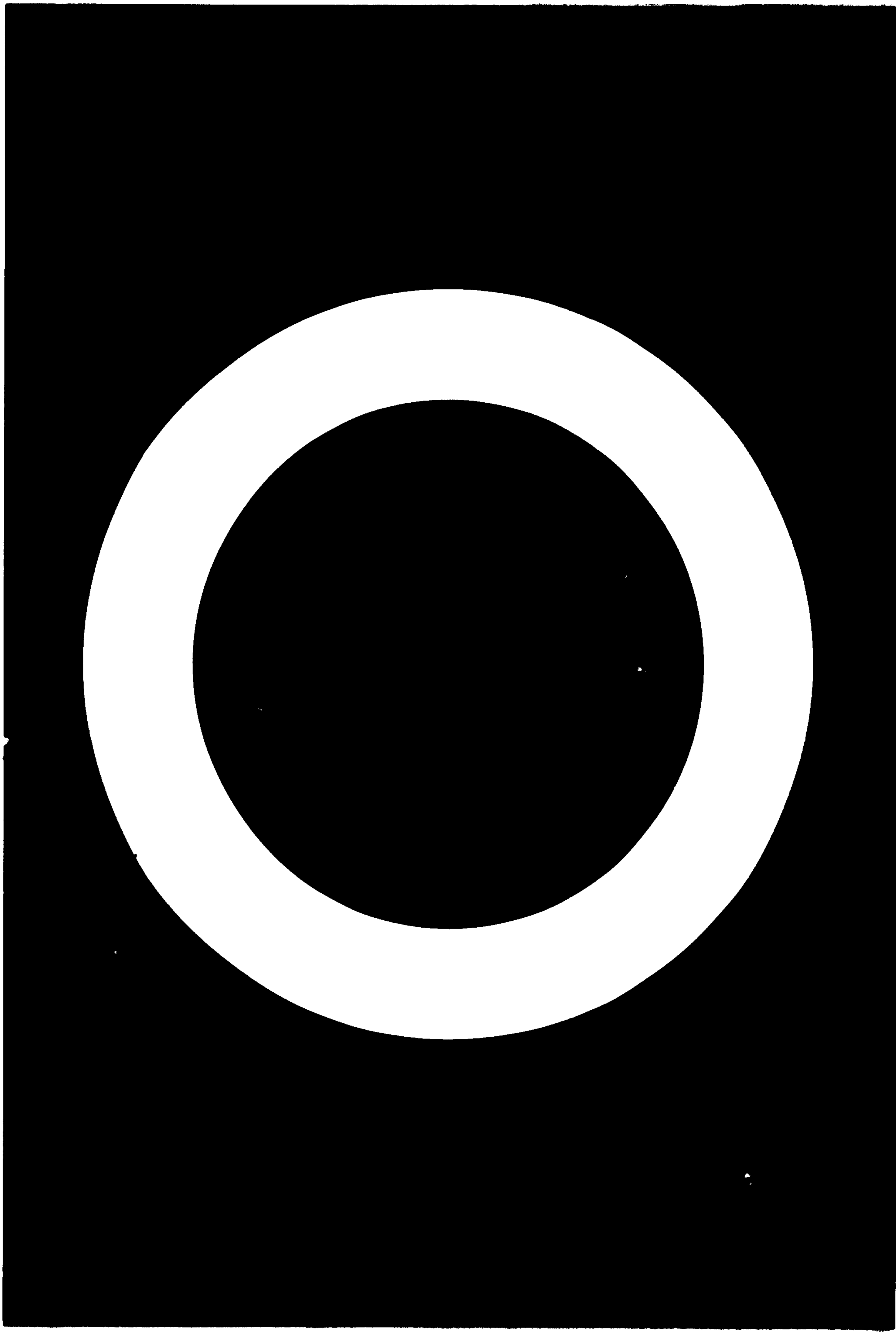
CNRS	Centre national de la recherche scientifique
ENSAM	Ecole nationale supérieure d'arts et métiers de Paris
RSS	Royal Scientific Society of Jordan

ABSTRACT

The project entitled "Assistance to Solar Energy Centre, Amman, Jordan" (SI/JOR/77/802) originated in a request by the Government of Jordan in April 1977 for the assistance of the United Nations Development Programme (UNDP) in obtaining basic solar energy laboratory equipment and carrying out a short course in solar energy research and applications. The request was approved in September 1977, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency, and the Royal Scientific Society of Jordan (RSS) as government co-operating agency. The one-month mission covered by this report took place in March 1978.

One of the main conclusions of the report is that there exist in Jordan very favourable conditions for undertaking an ambitious programme to expand the utilization of solar technology, with emphasis on applied research and development and the local production of the hardware needed for solar energy installations.

The report recommends, among other things, that a one-year solar energy project should be carried out if possible with the technical assistance of an international agency. The programme of activities would include the following components: the acquisition of equipment and materials, study tours, the provision of consultancy services, and the organization of courses on various aspects of solar energy.



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I. INTRODUCTION

The Royal Scientific Society (RSS), the main science and technology research institution in Jordan, has an active solar energy section within its mechanical engineering department. This section includes 10 engineers and has the possibility to use the technical services of a relatively well-equipped and well-manned workshop.

The main solar energy activity till now has been the construction of a 375 m^2 solar distillation plant in Aqaba and a 25 m^2 one in Amman. These solar stills utilize the principle of heat pipes. They were built in co-operation with a firm in the Federal Republic of Germany. The section has already constructed some samples of solar water heaters and a solar collector testing facility. The RSS is planning now to popularize the utilization of solar water heating systems and to find out, based on the testing of the solar stills already constructed in Aqaba and Amman, the feasibility of the solar heat pipes system, and to adapt it to the local conditions.

A new co-operation between the RSS and the Kuwait Institute for Scientific Research is being developed, and a joint research programme in solar space heating and cooling is under consideration.

In order to further its programme of applied research and development in the field of solar technology, the Government of Jordan made a request in April 1977 for the assistance of the United Nations Development Programme (UNDP) in obtaining basic solar energy laboratory equipment and carrying out a short course in solar energy research and applications. The request was approved in September 1977, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency, and the RSS as government co-operating agency. The project had a budget of $2,393.

The expert arrived in Amman on 2 March 1978 for a one-month mission with the following specific duties:

(a) To analyse the RRS solar energy programme in the Aqaba solar energy testing station, and the solar energy section of the mechanical engineering department in Amman;

(b) To outline a specific technical workplan and detail the assistance needed, including laboratory equipment and other inputs;

(c) To work out the details of the short course to be held on solar energy in the mechanical engineering department;

(d) To outline possible action that could be eventually undertaken by the solar energy centre of Jordan for the benefit of other developing countries in the Middle East.

II. FINDINGS

The last two years could be considered as a preparatory phase for intensive work in the field of solar energy. The main necessary equipment for the workshop and the laboratory has already been supplied. Additional laboratory equipment has been requested within the framework of the bilateral programme of co-operation with the Federal Republic of Germany. The solar energy section is realtively well staffed, the solar stills are ready for testing, and some solar collectors have been manufactured. The section could be considered at present as operational. Annex I contains a list of the equipment and materials that should be acquired under the proposed follow-up project.

A. Sea-water desalination

A systematic in-depth programme of research on the Aqaba and Amman plants is planned. Preliminary measurements have already been done in Aqaba. Measurements on the Amman plant are expected to start in April 1978. The utilization of heat pipes for solar water desalination could present a good technical solution, but it is necessarily a very expensive one. Regarding the efficiency of the system, it is difficult to give a valid opinion at the present stage, as the experiments have just started. The supplier predicts about 5 l/m^2 per day of distilled water against 3-3.5 l/m^2 per day for a well-designed and constructed conventional still.

The heat pipe system allows higher temperature, which is interesting in applications such as solar refrigeration and conversion of solar energy into mechanical energy. However, this range of relatively high temperature is not really necessary for sea-water desalination. The manufacturing of heat pipes could not be economically envisaged in the medium term in relatively small developing countries. In addition, the solar desalination heat pipe system needs a water-cooled condenser which requires an external source of energy to feed the circuit permanently or at least to fill a tank which in its turn feeds the condenser. Some technological problems are still to be resolved.

It has been proposed to design and construct a small demonstration conventional solar still which will constitute a preliminary prototype for larger ones. This duty has been done with the assistance of an engineer in the solar energy section. Hollow bricks and glass covers were used, and a rain gutter was built as a part of the concrete wall. For sealants, four solutions have been used:

metallic frame with silicone rubber; metallic frame with ordinary putty used in conventional metallic windows; metallic frame with adhesive rubber; and glass applied on concrete with silicone rubber. For the absorbent surface, butyl rubber and adequate special bituminous paint could not be found on the local market, so an ordinary bituminous waterproof paint has been used to test the system. As the mission did not foresee the design and erection of such a prototype and the bad weather did not allow proper testing of the system, the expert could not obtain meaningful measurement results.

Although the surface of the still is very small, and a good absorbent surface could not be obtained, the following points should be noted:

(a) Silicon rubber is a good sealant and does not present any technological problem. However, it is expensive, and a tar plastic putty (cold-applied plastic bituminous compound) should therefore be tested;

(b) Ordinary putty has been found to be inadequate for the above-mentioned application;

(d) Applying glass covers on the concrete with adequate preparation of the form of the concrete seems to be possible, however a larger quantity of silicon sealant will be used;

(e) The local available bituminous paint which has been applied is not adequate for such uses, the melting point of this paint being relatively low in comparison with the 50^{o}-60^{o}C level which the water temperature could reach.

The percentage of shadowed surface is higher in case of small surfaces, and it is expected that the efficiency of the still (number of $1/m^2$ of distilled water per day) will not be as good as in the case of larger surfaces. Also, the height of the basin could be reduced to about 150 mm instead of the 250 mm in the case of the prototype.

Different water depths in the basin should be tested, starting with 20 mm in the upper level of the basin. It is well known that large depths of water present a higher thermal inertia, and the still continues producing later on in the day. With a low water depth the still starts producing earlier, but stops producing earlier too.

As a preliminary conclusion it could be said that the conventional system presents for the moment and in the local conditions a better solution. It utilizes mainly local materials, is easy to construct, needs less investment and is cheaper, and the cost per liter of distilled water obtained will certainly be less.

In order to make objective comparisons of heat pipe stills and conventional stills (concrete or aluminium structure, glass covers, butyl rubber or special bituminous paint, different sealants), it is necessary to build a certain number of conventional stills of different shapes, dimensions and materials. It is proposed to construct at least two stills of from 25 to 30 m^2 each and some small stills of from 4 to 8 m^2 each. The following parameters could be studied: angle of inclination of the cover; depth of the water; programme of feeding, emptying and flushing of the still; reliability of used materials; and cost of materials. It would be useful to design a small transportable still of simple and cheap construction, with a surface of about 2 m^2. This type of still could be popularized in the service stations for producing distilled water for batteries.

B. Solar water heaters

A testing facility for solar water heaters is now operational. Some solar collectors of different design have been manufactured. The collector is made of ½ inch steel pipes and steel sheets welded together continuously or on short spaced distances to allow the study of the thermal contact. The distance between the ½ inch tubes is 4 inches. One and two glass covers will be tested. The hot water tank is connected directly to the solar collector without a heat exchanger. This solution is easier and cheaper, but after some time solid particles could deposit and the overall (global) heat exchange coefficient will decrease with time.

Different insulation materials (fibreglass, polyurethane, polystyrene) will be tested. It is recommended to test the possibility of using some local materials such as sawdust and straws (after a special treatment against insects and fungi). Large water heater systems will be studied for hotels, schools, hospitals etc.

C. Solar drying and refrigeration

Research and development activities in solar drying have not yet been initiated at the RSS. Such activities are very important for Jordan, as large quantities of vegetables and fruits could be saved or better preserved. Solar drying in comparison with traditional drying of food and animal products is cleaner and quicker and gives better results in terms of taste and appearance.

Small-scale solar drying technology is relatively well established. A considerable amount of research and development activity has been undertaken for a number of years, and a large number of publications and findings exist.

It is recommended that the RSS start urgently to construct several types of driers of simple design and simplified technology in order to enable the farmers to construct their required solar driers with local materials.

Special research should be conducted to determine for each important fruit and vegetable the thickness of the slice, the percentage of filling of the drier and the optimum temperature-time curve. Evaluation of the prototypes should be carried out, with particular reference to the cost and the lifetime.

In addition to the joint programme of research established by Kuwait and Jordan in the field of solar space heating and air conditioning, it is advisable that the RSS design and build two small solar refrigeration units locally, one unit with ammonia water, the other with lithium bromide.

D. Solar energy conversion

As of today, there are different systems for the conversion of solar energy into mechanical energy on the international market, but only very few systems have been tested in real work conditions. These systems are still very expensive, and it is difficult within the small budget which could be allocated by UNIDO to the RSS solar project to select more than a small installation.

In 1976 UNIDO approached the Ecole nationale superieure d'arts et metiers de Paris (ENSAM), where a reciprocating engine has been developed, with a proposal to co-operate in a small solar project. The ENSAM is now ready to start this co-operation. The engine is of a simple design and relatively reasonable cost. The project could probably be implemented with the support of the Centre national de la recherche scientifique (CNRS). It is difficult at this stage to define detailed specifications of the system, and in particular the working temperature. This temperature will determine the type of solar collector used.

A budget of $15,000 could cover the UNIDO participation. It is recommended to implement this project with the ENSAM and the CNRS, as they are non-profit-making organizations of high scientific and technological experience.

E. Solar energy courses

In order to promote the utilization of solar energy, training of personnel is of high importance. Several engineers of the solar energy section at the RSS have been trained abroad. However, it is felt that training of other engineers and scientists in the section, as well as those of other public bodies interested in developing or using solar energy equipment, is badly needed.

Organizing an in-depth solar energy course needs long preparation. The RSS is willing to start such a course as soon as possible. A reasonable solution is to implement the course in two phases. A one-week course emphasizing urgent topics could be held in September 1978, and a one-month course could be held around April 1979.

The first course would concentrate on the following matters: sea-water desalination; refrigeration, space heating and air conditioning; and solar water heating.

The first day of the course would deal with general applications of solar energy. Arabic will be used the first day. A large number of executives, engineers and scientists interested in solar energy would be invited to participate in the first day of lectures and discussions. The following days would be reserved for the regular participants and English would be used.

The one-month course would be open for partioipants from other neighbouring Arab countries. The first day of this course Arabic would be used. The course would be conducted as s seminar, each session starting with a lecture followed by discussions, with exercises and preliminary designing in some cases. On this occasion specific design, construction and manufacturing aspects would be handled. An exhibition of solar equipment could be arranged during the course. Annex II outlines the contents of the course.

III. RECOMMENDATIONS

1. The solar energy programme in Jordan should include specific activities in the areas of solar desalination, drying, heating, air conditioning, refrigeration, conversion of solar energy into mechanical energy and solar pumping. This effort should involve other countries of the area and be made in co-operation with the existing institutions.

2. A solar energy project should be undertaken with UNIDO assistance. The duration of the project would be one year, starting in June 1978. The project would involve the following components:

Component	Cost ($)
Equipment	28,000
Study tours	5,000
Consultants	12,000
One-week course	10,000
One-month course	15,000

The intensive one-week course would cover the technical aspects of desalination, space heating, air conditioning and water heating, and would be attended by engineers who will undertake future work in the solar energy field. The study tours would make it possible to compare the findings and recommendations with the status of research and application of solar energy principles in other countries. About 40 specialists from the different countries in the region would be invited to attend the one-month course, which would be organized with the co-operation of UNIDO and other institutions, and would cover specific design, construction and manufacturing aspects of solar technology.

3. During the execution of the above-mentioned project, a meeting of those responsible for solar energy institutions in the Arab countries members of the Economic Commission for Western Asia should be organized in order to co-ordinate research and development activities and to study the possibility of creating a regional centre for solar energy.

4. When the solar energy prototypes developed in the RSS become satisfactory, the design should be put at the disposal of existing industries. As the market for solar equipment in the medium term will be relatively small, and the creation of specialized factories therefore unnecessary, this type of equipment should be manufactured in existing industries, such as the metallic furniture industry.

5. Special incentives should be studied to encourage the utilization of solar equipment manufactured within the country.

Annex I

EQUIPMENT AND MATERIALS

Quantity	Specifications	Indicative price ($)
1	Vacuum pump $\simeq$ 75 l/m, $\leqslant$ 0.1 microbar	500
2	Hand-operated vacuum pump $\simeq$ 0.1 l/stroke	100
2	Chemical hand-operated pump (lever or rotary) for pumping ammonia butane, $\simeq$ 0.3 l/stroke, steel or cast iron	250
1	High-pressure hand-operated pump $\geqslant$ 50 bars for testing vessels and pipes	150
3	Hot-water circulating pump, 3 m^3/h, 3 m manometric head, up to 90°C	300
1	Electronic tachometer up to 20,000 rev/min	200
10	Thermostats of different temperature ranges	200
6	Immersion heaters, 500 W, with thermostats	300
6	Different elements of solar collectors, 2 m^2 each, consisting of aluminium rollband, copper, steel, plastic, with vacuum and selective surface, only two collectors to be supplied with casing	
1	Continuous (endless) welding machine for steel sheets up to 2 mm	3,000
1	Kit welding and cutting torch for welding steel sheets up to 10 mm and cutting up to 200 mm	500
1	Torque wrench up to 26 mkp	50
1	Plates and profile steel shear with trip mechanism to cut plates of L-steel and T-steel at 90° and 45°; Flat steel up to 80 mm x 12 mm; L-steel, 50 mm x 6 mm; T-steel, 50 mm x 6 mm; Round steel, 20 mm; Squared steel, 18 mm; Squared trip mechanism; L-steel and T-steel, 50 mm x 5 mm; Three square trip; Mechanism for 50 mm x 5 mm L-steel and T-steel	1,450 (together with the following items)
1	Electric 2-speed half-inch protable drilling machine;	
1	Electric protable shear for plates similar to type 1504 Bosch, thickness of 2 mm with extra cutters;	
1	Electric portable shear for plates, 1.2 mm maximum thickness, type QsZ 636 - 1	
1	Angle grinder, grinding wheel diameter of approximately 250 mm	

Quantity	Specifications	Indicative price ($)
1	Solar engine $\geqslant$ 1 kW	15,000
10	Drums of 20 kg each, tar plastic, cold-applied plastic bituminous compound	200
10	Drums of 20 kg each, tank mastic special bituminous paint used for application on the inside of the drinking water tanks for protection against corrosion	200
200 m^2	Butyl rubber approximately 1 mm thick	300
20 kg	Silicone rubber adhesives sealant in container of about 300 grams	300
250 kg	Polyester with about 80 m^2 of fibreglass (glass mat of about 200 g/m^2) with 5 kg gel coat	750
	Cold spray galvanzied in small containers	250
	Materials to be bought locally: sheets (aluminium, copper and plexiglass), tubes (stainless steel, aluminium and copper), different fittings and special valves in bronze and cast iron, solvents	4,000
	Total	28,000

Annex II

SOLAR ENERGY COURSE

Duration of course: four weeks, five working days/week, six h/day

	Number of days
A. Basic information	
Solar energy utilization	1
Solar radiations: characteristics, instruments and measurements	1
Instruments and measurement of fluid mechanics and heat transfer parameters	1
Solar flat-plate and focussing collectors: fundamentals, design, materials, manufacturing and cost	2
Heat storage: fundamentals, materials, technology and cost	½
Corrosion in solar equipment	½
B. Solar systems	
Sea and brackish water desalination: fundamentals, systems, materials, equipment, erection and cost	2
Solar drying: fundamentals, systems, materials, equipment, manufacturing and cost	1
Solar cooking: fundamentals, systems, materials, manufacturing and cost	½
Solar greenhouses for agricultural applications: state of the art	½

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