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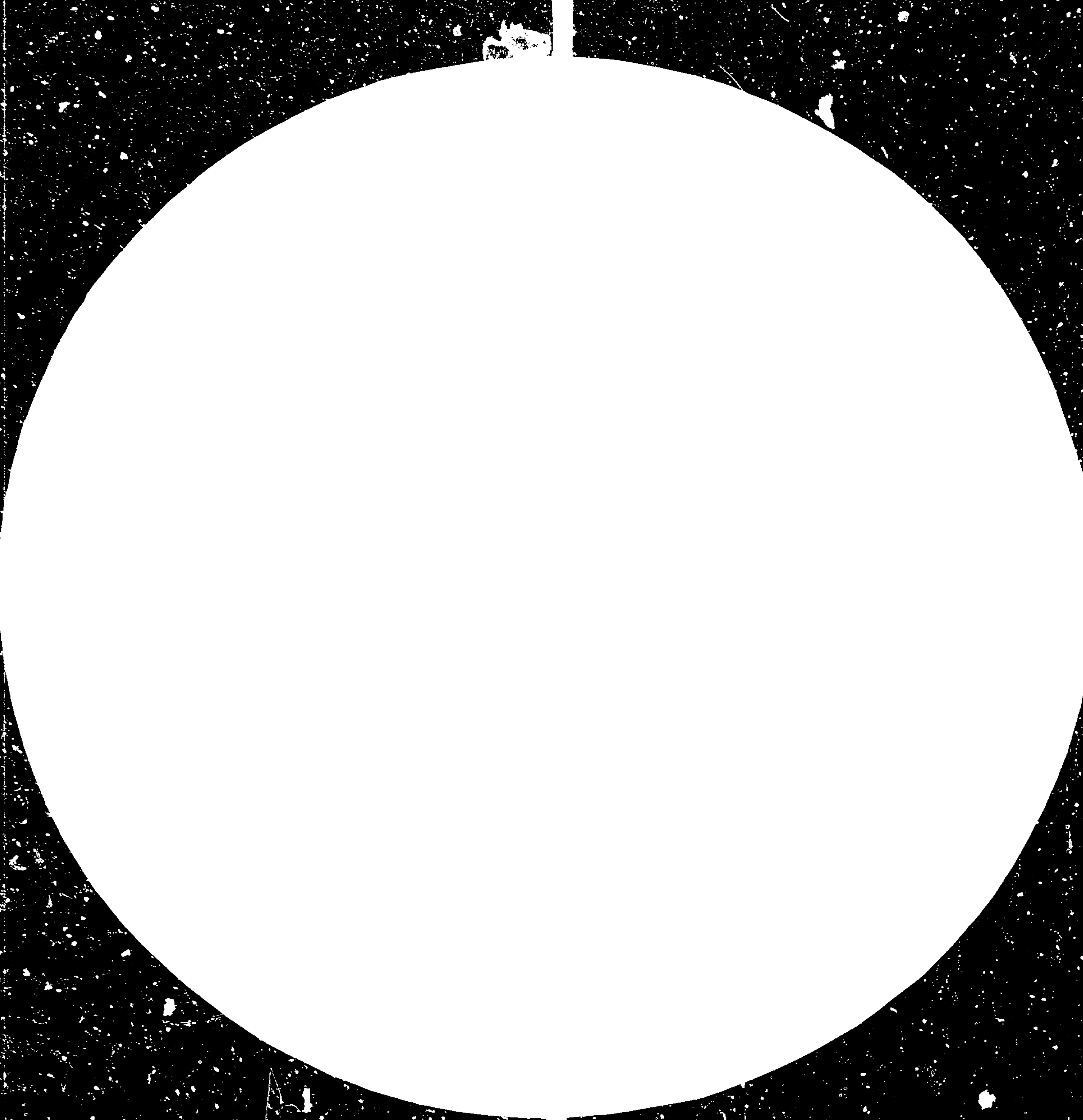

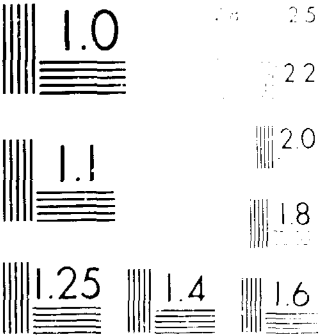
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USE OF SOLAR ENERGY

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AFGHANISTAN

Technical report: Preliminary estimates and recommendations *

Prepared for the Government of Afghanistan
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of S.I. Smirnov,
expert in solar energy

United Nations Industrial Development Organization
Vienna

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SUMMARY

This report reflects the results of an assignment involving two months of work in Afghanistan (January-February 1982) by Mr. S. I. Smirnov, UNIDO expert on solar energy.

The basic purpose of the assignment was to evaluate the local conditions and prospects for the use of solar energy in Afghanistan.

The report points out that, because of the scarcity of conventional fuels and the difficulties in delivering them to certain regions of the country, the favourable climatic and actinometric conditions, and the prevalence of scattered small-scale energy consumers, a propitious situation exists for the wide use of solar energy, especially in the community and household sector of the economy. Calculations indicate that, under the conditions of Afghanistan, capital costs for solar-energy systems to heat water and premises and cook food can be recouped through fuel savings within substantially shorter periods than the life-time of the systems themselves.

CONTENTS

INTRODUCTION

The author of this report arrived in the Democratic Republic of Afghanistan in January 1982 on a two-month assignment as a UNIDO expert in solar energy. This assignment involved the following tasks:

- An assessment of the information on the use of solar energy under the conditions of Afghanistan, and an evaluation of the feasibility of such use;
- An investigation into the possibilities for the practical use of solar energy in the home and in housing construction, industry and agriculture, and also into the conditions for the local manufacture of the equipment for solar-energy systems;
- The transmission of the author's experience in the use of solar energy to his Afghan colleagues.

These tasks were not subject to review or modification during the course of the assignment.

UNIDO has been assisting the Government of Afghanistan in accordance with the Government's official request of 31 October 1978.

At present, no work is being conducted in Afghanistan with respect to the use of solar energy and there are no specialists in the country capable of conducting such work, even though on the part of the responsible governmental authorities (State Planning Committee, Ministry of Mining and Industry, Ministry of Public Works, and others) there is a clear understanding of the importance of research and practical measures in this area. The prospects for the use of renewable energy resources, and solar energy in particular, in Afghanistan were regarded as excellent in that country's report to the United Nations international conference on new energy sources, held in Nairobi, Kenya, in 1981. 1/

In accordance with one of his assigned tasks, namely the transmission of experience in the use of solar energy to his Afghan colleagues, the author delivered five lectures on solar heating for staff members of the Department of Technical and Economic Studies of the Ministry of Mining and Industry;

1/ The report in question was prepared by United Nations expert, I. N. Milev.

in addition, he conducted a three-day seminar for a wide range of specialists from that ministry and from the State Planning Committee, at which he acquainted them with the results of his work in the country. This seminar was attended by some 40 persons all told.

This report consists essentially of four chapters which discuss the climatic and actinometric conditions in Afghanistan, the country's fuel and energy resources, and special factors in the supply of fuel to the Afghan public; they also contain technical and economic assessments of the possible use of solar energy in various economic sectors, including such applications as the heating of water for household needs, the heating of houses of limited size, and the cooking of food.

In the course of preparing this report, the author discussed the problems in the use of solar energy in Afghanistan with a number of Afghan specialists (see annex 0)., Mr. I. N. Milev, and also with the Soviet advisers to various ministries and organizations. To all these persons, the author wishes to take this opportunity to express his deep gratitude for their many useful thoughts and suggestions.

The author is also grateful to the UNDP Resident Representative in Kabul, Mr. J. Schütz-Müller, for the interest he showed in this assignment.

Finally, the author owes a particular debt of gratitude to his counterpart, Mr. A. A. Azizi, for his many efforts in collecting the information required for this study and for his valuable advice and suggestions.

I. FUEL AND ENERGY RESOURCES OF AFGHANISTAN

Afghanistan has sizable reserves of fossil fuels. The country's proven industrial reserves of natural gas total 80 billion cubic metres, of coal 79 million tonnes, and of oil 11 million tonnes. The levels of extraction of these fuels and of the production of electrical energy over the last five years are shown in table 1 of annex I. In addition, Afghanistan imports petroleum products (the figure was 275,000 tonnes in 1981-1982, including some 15,000 tonnes of kerosene).

An understanding of the structure of energy resource consumption is important for an assessment of the outlook for the use of solar energy. Afghanistan exports approximately 90 per cent of its natural gas to the USSR; in 1980-1981, gas sales totalled 233 million dollars and accounted for one-third of all the country's foreign currency revenue. The remaining gas is used as raw material at the Mazari-Sharif Nitrogen Fertilizer Plant (about 6 per cent) and also for direct local requirements at the gas fields themselves.

So far, oil plays no significant role in Afghanistan's fuel-energy balance. In recent years, extraction has been at the level of 13,000-16,000 tonnes, essentially representing the result of experimental pumping. At the present time, oil extraction has ceased altogether.

Virtually all the coal mined in the country is used for industrial needs and for general local applications. In 1979, the coal consumption balance was as follows:

Cement industry	45,000 tonnes
Light industry	40,000 tonnes
Food industry	12,000 tonnes
Remaining industrial branches	30,000 tonnes
Needs of the population	40,000 tonnes

It is worth while noting that at present no coal at all is being used in Afghanistan for energy needs. Hydroelectric power stations predominate in the electrical energy production infrastructure. As of today, some 80 per cent of all electrical energy is consumed on the community-household level (mainly in Kabul) for the heating of homes and the cooking of food. Nevertheless, during the autumn-winter peak Kabul experiences a power shortfall, which has been sharply aggravated in recent years as a result of the cutback in coal mining. The severe shortage of coal and electric power, especially for household needs, is offset by the use of firewood, the procurement of which is largely in the hands of the private sector. During the winter season the market price for firewood in Kabul is 8-10 afghanis per kilogram (5-6 afghanis per kg in the summer).

The prices of other fuels and electric energy are given below:

- Kerosene	$\frac{7}{21.1}$	afghanis/litre 2/
- Coal	854	afghanis/tonne
- Electricity	1.0	afghanis/kW/hour.

The principal fuels used in Afghanistan for heating houses, cooking food etc. are firewood, twigs, dry grass, brushwood, and dried manure. According to estimates compiled by specialists of the State Planning Committee, these fuel varieties account for about 85 per cent of the total. The real annual consumption of firewood for the country as a whole is not known.

Afghanistan is not particularly rich in wooded areas, with forests covering 1.9 million hectares or about 3 per cent of the national territory. An important task is to determine whether the country's woodland resources are shrinking or whether the felling of timber for firewood is being compensated by the natural growth of the forests.

Because of the expansion of industry, the next few years will see an increase in the requirement for fuels in Afghanistan, and it is difficult to imagine that the problem of fuel shortages will not grow even more acute. It is for this reason that the use of solar energy as a means of reducing the fuel deficit is so extremely topical in this country.

2/ The numerator indicates the government price, the denominator the market price. It should also be noted that the prices charged the State for petroleum products are close to the market prices.

II. SPECIAL FACTORS IN THE SUPPLY OF FUEL TO THE AFGHAN PUBLIC

Because of the nature of the country (the predominance of mountainous and desert regions where access is difficult), a characteristic feature of Afghanistan is the inadequate integration of the various sections of the nation. Certain of these regions are connected to other parts of the country by nothing more than caravan routes or paths which can be negotiated only by pack animals. Because of the bad weather, especially during the winter, the result is that individual communities and settlements are cut off for long periods.

Railway communication in Afghanistan is non-existent, and because of natural conditions its introduction is extremely difficult. In addition, the country's road system is poorly developed; as of today, the total length of primary and dirt roads is 18,500 km - that is, about one metre per inhabitant. Moreover, only half of these roads are usable throughout the entire year. There are very few transport vehicles (see table).

Vehicle type	State sector	Private sector
Trucks, units	5 848	13 504
Buses, units	1 660	9 024
Cars, units	8 381	18 114

Considering that nearly 90 per cent of Afghanistan's population is engaged in agriculture and either lives in small communities or engages in a semi-nomadic (nomadic) way of life, the country may be said to exhibit the following characteristic features:

- The predominance of scattered, small-scale energy consumers;
- Objective difficulties in organizing the supply of traditional energy resources to a number of regions in the country and, where these difficulties can be overcome, the high cost of the fuel delivered.

These factors will undoubtedly prove conducive to the extensive use of solar energy in Afghanistan.

III. CLIMATIC AND ACTINOMETRIC CONDITIONS IN AFGHANISTAN

A. Air temperature

The temperature conditions in Afghanistan are the subject of a detailed study in a monograph by V.I. Titov. (1) Table 1 of annex III includes data from this work on the mean-monthly and mean-annual air temperature readings for 15 localities. When assessing conditions for the use of solar energy, in addition to the average values it is of interest to analyse the degree of variation in air temperature over a 24-hour period.

In the mountain valleys and depressions of Afghanistan during the summer the intense daytime heating of the air to average temperatures of as much as 25-29° C (with peaks of 32-34° C) gives way at night to an abrupt cooling of the air, with temperatures falling on the average to 5-7° C and occasionally to below zero. A similar pattern occurs during the winter as well. As may be seen in table 1 of annex III, the average temperature during January in the south and southwest of Afghanistan is 5-7° C; at the same time, the daytime air temperature in these regions is normally 13-16° C and on individual days during January may climb to 25-29° C. Meanwhile, at night there is a marked cooling of the surface of the earth, with the air temperature in half and more than half of the instances falling to below zero. In this way, under Afghanistan conditions the average daytime air temperature values (it being precisely this temperature which determines the operating efficiency of solar energy installations) are 8-10° C higher than the average daily readings. Consequently, the use of the average daily temperature values in solar energy calculations results in a marked under-estimation of the operating efficiency of the equipment. In other words, calculations of the caloric power of solar energy installations which are based on average daily temperature values involve a certain margin; in the case of Afghanistan, it can easily be shown that this margin amounts to 20-25 per cent.

B. Duration of sunshine

As is evident from table 2 of annex III, the duration of sunshine in Afghanistan is very long: in the north of the country it amounts to more than 2,500 hours, in Central Afghanistan it exceeds 3,000 hours, and in the southern regions it totals nearly 3,500 hours.

During the summer period (from June to September) throughout the country the number of hours of sunshine, as a percentage of the possible total, amounts to 70-85 per cent (almost 90 per cent in Kandahar). In the autumn (October and November) the probability of cloudless weather is also very high: more than

60 per cent in the north, about 80 per cent in Kabul, and from 70-85 per cent in the south. In the winter (December to February) weather conditions in the northern and southern regions of Afghanistan are substantially different. In the north during approximately two-thirds of the time in the winter the sky is overcast, with low clouds and frequent precipitation; accordingly, the number of hours of sunshine in the northern regions in the winter amounts to only 40-50 per cent of the theoretically possible. In Kabul the winter figure is considerably higher at about 60 per cent, while in the south it is higher still - from 60-70 per cent.

C. Solar radiation

Measurements of total and diffuse incident solar radiation were taken at seven meteorological stations in Afghanistan:

- Darlamon* (1974-1979);
- Ghaziabad* (1973-1979);
- Darweshan (1977-1979);
- Sarde-Ghazni* (1977-1979);
- Kutgai (1978-1979);
- Chardara-Kunduz (1973-1978);
- Baghlan* (1978-1979).

At the present time, four of these stations (marked with an asterisk) are in operation. The results of the actinometric observations at the Darlamon station are shown in table 3 of annex III. It is likely that the processing of the data from the remaining stations will be completed by the end of 1982. By way of comparison, table 3 contains data for Tashkent (USSR), Fresno, California (United States), and Jerusalem, where the use of solar energy in heating systems is regarded as economically sound. It will be seen from the table that the annual influx of total solar radiation at Darlamon is considerably (27.5 per cent) greater than at Tashkent, higher than at Fresno, and only slightly lower than in Jerusalem. Thus, Darlamon belongs to the "sunniest" regions of the world. It is important in this connection to note that the higher annual total of incident radiation at Darlamon comes about mainly because of the higher influx of solar energy during the winter months. For example, in January the uptake of solar radiation at Darlamon is nearly 85 per cent greater than at Tashkent and 30 per cent greater than at Fresno, whereas in the summer it is approximately equal. These data indicate that at least in Central Afghanistan there are good possibilities for the use of solar energy for those applications in which energy is required only in the winter (e.g., for heating buildings) as well as for applications in which there is a uniform energy requirement the year round (e.g., for heating water for household needs, cooking food etc.).

Finally, we might note that, on the basis of the sunshine duration data for Afghanistan (table 2, annex III), Kabul belongs to the regions with average solar energy potential.

D. Winds

Over a considerable portion of the territory of Afghanistan, the average monthly wind velocity values do not exceed 4 metres/second. The strongest winds (up to 6.5 m/sec and, in some years, up to 9 m/sec as a monthly average) are found in the summer at Herat and in the mountains, and also on the Ghazni-Kandahar plateau, where the average monthly wind velocity exceeds 4 m/sec almost the entire year. Since it is calm a considerable portion of the time (up to 50 per cent), the wind velocities during windy weather will be substantially higher. Not infrequently, there are gusts which attain hurricane force, i.e., 25-30 m/sec (table 4 of annex III).

In a number of regions in Afghanistan, mainly during the summer and when the wind is high, dust and sand storms occur. The following table (1) indicates the number of days a year when such storms take place:

- Kunduz	46.2
- Shibarghan	39.8
- Kabul	15.3
- Logar	3.6
- Jalalabad	7.0
- Kandahar	72.1
- Lashkar	30.8

These wind pattern characteristics give rise to the following structural requirements for the construction of solar energy facilities:

- The load-bearing components of the structure must be capable of withstanding loads arising at wind velocities of 35 m/sec;
- The reflector surfaces of the focusing collectors must be reliably protected against higher-than-usual erosion due to dust and sand.

Undoubtedly, in a number of regions in the country (Kunduz, Shibarghan, Kandahar, Herat and others), these requirements will complicate the use of focusing collectors, except possibly for solar cookers where they might easily be retracted into the building at the approach of a storm or hurricane.

It is also necessary to point out that in regions with frequent dust storms the economic performance of solar energy systems will be significantly lower, because, after the storm, the dust settles very slowly, over a period of several days; during such times, the transparency of the atmosphere and the level of incident solar radiation are quite low. This limitation does not apply to solar heating systems, since during the winter period the number of days with dust storms anywhere (with the exception of Kandahar) is small - one or two a month.

IV. BASIC TRENDS IN THE USE OF SOLAR ENERGY IN AFGHANISTAN

Solar energy is currently being used throughout the world for the most varied applications. Depending on the purpose for which this energy source is used, there are differences in the structural complexity of the systems, the feasibility of repairing them under actual operating conditions, the availability of the materials needed for the equipment, their economic performance etc.

Under the conditions typical of Afghanistan, the following applications for solar energy are both economically justified, technically feasible, and practically meaningful:

- The heating of water to temperatures of 70-80° C for household needs and technological processes in industry;
- The heating and hot-water supply of houses of limited size;
- The cooking of food.

In selecting these areas of application for solar energy, consideration has been given to the following factors:

- The possibility of extensive use on a nationwide basis and the prospects for realizing significant fuel savings;
- The possibility of domestic production of the basic components of the systems;
- Simplicity of maintenance and repairability under actual operating conditions;
- Economic soundness.

A. <u>The solar heating of water for household needs</u>

In assessing the efficiency of solar energy in heating water for household needs, the analysis is based on the climatic conditions of Kabul and assumes a solar installation for a single family consisting of seven persons. It was further assumed that the solar energy is collected and transformed into heat energy by means of the simplest kind of collectors, of the flat variety, with a single layer of glass and a non-selective absorbing surface; these collectors were, moreover, assumed to be facing towards the south and inclined to the horizon at an angle equal to the latitude of the locality (about 35° north latitude). The heat from the collectors is fed to a storage tank through the natural circulation of the heat-transfer agent and transmitted to the water, of which the tank contains 75 kg per square metre of collector area.

The calculations, performed using the f-chart method (3) showed that assuming a collector area of 5.6 m^2, the system is capable of providing a daily average of about 285 litres of water at a temperature of 55° C 3/ or 4.68 million kilocalories of heat a year (without the use of a supplementary energy source). The amount of firewood which would be needed to produce this amount of heat in a year is 3.9 tonnes; 4/ at 7 afghanis a kilogram (the average yearly price), the cost of this firewood would be 27,300 afghanis. The costs of a solar system of the kind considered, under domestic conditions, amount to about 32,400 afghanis (see annex IV-A). Thus, the costs for the household water-heating solar system can be recouped, under the conditions typical of Kabul, in the form of savings on firewood in less than a year and a half. As indicated by long years of practical experience in many countries of the world, the life-time of such a system is at least five years.

The extensive use of solar energy for water-heating for household needs will undoubtedly contribute to lowering the incidence of contagious and parasitic diseases in the country. An estimate of the resultant economic and social impact is outside the framework of this report, but there is no question but that these effects can be very significant.

B. The use of solar energy for the heating and hot-water supply of homes

In Afghanistan there are heat-supply (and drainage) systems only in multiple-dwelling residential buildings, of which there are still not many, and in public buildings (ministries, the university, the polytechnical institute etc.). Neither in previous years nor at present have the plans for single-family homes or buildings with just a few apartments called for the installation of systems of this kind.

3/ During the summer the quantity of hot water will be greater, about 350 litres a day; during the winter it will be less, about 180 litres a day.

4/ The reference is to dry firewood with a specific weight of 400 kg/m^3. The heat-generating capacity of the local firewood varieties and the stove efficiency were assumed to be 3,000 kCal/kg and 0.4, respectively. These figures were obtained from specialists of the Central Institute for Building and City Planning in Kabul.

For the purposes of this report, the assessment of the efficiency of solar energy for heating has been based on the climatic conditions of Kabul, using as an example a four-apartment two-storey residential structure, of the kind designed at the Kabul Central Institute for Building and City Planning under the direction of Dr. S.S. Housain. The facade of the unit and also the plans of the first and second floors are shown in annex IV-B. On the first floor there are the living room and kitchen for each apartment, while the two bedrooms and lavatory occupy the second floor. The floor space and volume of one apartment total 43.15 m^2 and 237.6 m^3, respectively (the height of the rooms is 2.75 m). The heat loss intensity is fairly high - 1,163 W/° C for the unit as a whole. 5/ The monthly heating and hot-water load values for the unit are shown in table 1 of annex IV-B.

The heating load was taken to be proportional to the heat loss intensity of the unit (1,163 W/° C) and the temperature difference (18-Ta), where Ta is the average monthly temperature of the external air (see table 1 of annex III). It was assumed, in this connection, that the internal heat sources (electric household appliances, lamps, the heat released by the occupants etc.) and also the solar radiation entering the house through the windows would cause a rise in temperature from 18° C to the more comfortable level of 21-22° C.

The hot-water load was determined on the basis of the following considerations:

- Total number of persons in the unit	20
- Daily consumption of hot water	100 litres/person
- Nominal temperature of the hot water	55° C
- Nominal temperature of the cold water	4° C from November to March and 10° C during the remaining period of the year.

It will be seen from table 1 of annex IV-B that at 67 per cent the annual heating load accounts for a very high proportion of the total heat load.

In this report, we shall be considering an active solar heating system consisting of three circuits:

- A collector circuit within which a non-freezing liquid circulates (e.g., a 50 per cent aqueous solution of ethylene glycole) drawing off the heat from the solar collectors to the heat-exchanger. Anti-freeze consumption rate: 0.015 litre/m^2/sec;

5/ At the author's request, the heat losses were calculated by Engineer Najib, one of Dr. Housain's colleagues.

- A storage circuit connecting the heat-exchanger to the water storage tank (capacity: 75 litres per square metre of collector area);

- A heating circuit connecting the storage unit with the water-air heat-exchanger in which the air released into the premises is heated. The efficiency of the heat-exchanger is 0.4. When there is insufficient solar heat, the premises are heated by traditional means (e.g., a stove).

The thermal characteristics of the solar system for the heating and hot-water supply of the dwelling unit were calculated for equipment using flat solar collectors with a double layer of glass and a non-selective absorbing surface. The following are the basic parameters of the collector:

- Optical efficiency	0.75
- Over-all loss factor	4.5 $W/m^2/^\circ C$
- Collector heat extraction factor	0.85

The collectors were assumed to be facing southward and inclined to the horizon at an angle 15° greater than the angle of latitude.

The results of the calculations carried out by the f-chart method, (3) are shown in table 1 of annex IV-B and in figure 1. In both the table and figure, f represents the fraction of the total (for heating and hot water) heat load of the unit obtained through solar energy. Naturally, as the area of the solar collectors increases, there will also be an increase in the contribution of solar heat and, accordingly, in fuel savings. As is clear from the figure 50 per cent fuel savings can be realized with a collector area A of 90 m^2; further increases in this area will be less effective. For example, with the collector area increased from 90 to 150 m^2 (i.e., by 67 per cent), the fraction of the load covered by the solar energy rises from 0.5 to 0.65, i.e., by only 30 per cent. For this reason, the estimate given below of the economic efficiency of a solar heating system for the unit assumed a collector area A of 90 m^2.

All told, the amount of fuel (firewood) 6/ saved in a year by the housing unit equals 43.9 tonnes, while the yearly savings for this fuel, at a price of 7 afghanis per kg, total 307,300 afghanis.

6/ The figures for the heat-generating capacity of the firewood and the efficiency of the stove are assumed to be the same as in the preceding section.

In estimating the capital investment required for a heating and hot-water supply solar system for the unit as a whole

$$K = C_1A + C_2 \text{ (afghanis)},$$

we multiply the value of the specific costs C_1 by 25 per cent over the value found in the cost calculation for the water-heating solar unit for household needs (see annex IV-A), and we assume that the costs C_2 (these refer mainly to the costs for the heating circuit and the heated-air distribution system in the building) are equal to one-half the costs C_1A. 7/ Thus,

$$K = 1.5 \times 1.25 \times 5{,}800 \times 90 = 978{,}700 \text{ afghanis.}$$

This investment is recovered in the form of firewood savings in less than three and a half years.

Assuming that one cubic metre of living space costs 3,000 afghanis, the cost of one apartment is 712,800 afghanis. In turn, the cost of a solar heating system in terms of one apartment is 244,700 afghanis. Consequently, the addition of the solar heating system increases the cost of the apartment by 34.3 per cent.

Along with active solar heating systems, passive systems of the "Tromb wall" type can also be used in Afghanistan. These systems have proved themselves in practice in many regions of the world, including at Chauvency-le-Château (Metz, France, 50° north latitude), Wallasey (near Liverpool, Great Britain, 53° north latitude), Corrales (near Albuquerque, New Mexico, United States of America, 35° north latitude), Termez (near Tashkent, USSR), and other localities. For example, in the solar house located at Wallasey, where the average annual outside air temperature is 10° C (at Kabul it is higher at 10.9°C) and the yearly influx of total solar radiation incident to a horizontal surface is about 0.8 gigacalories/m^2 (at Kabul it is more than double that at 1.7 Gcal/m^2), the following temperature pattern has been sustained over 20 years without any supplementary heating:

- From June to October 18-24° C
- From November to February 16-20° C
- From March to May 17-21° C

7/ The costs C_2 can be more accurately estimated when a house incorporating a solar heating system is in the planning stage.

These data demonstrate the excellent prospects for the use of passive solar heating systems in Afghanistan. Unquestioned advantages of these systems, which are particularly important in a country like Afghanistan, are their minimal requirement for technical maintenance and their simplicity of operation and repair. Estimates of the specific economic efficiency of this approach would require at least rough plans of a solar home incorporating a passive heating system.

C. The preparation of food

Within the space of a year, approximately 0.2 e.f.t./person 8/ are expended for cooking. In Afghanistan, the principal fuels for the home oven are firewood, twigs, brushwood, dried manure etc. Assuming that firewood accounts for half of the fuel consumed in cooking food, the country's annual consumption of this fuel variety will be about 3 million tonnes. Considering the limited wooded areas available and the advisability of employing the wood in various sectors of the economy, for example, in the woodworking industry, the use of solar energy in Afghanistan for cooking must be regarded as very timely and of great practical importance.

At the present time, a number of types of solar cookers have been designed and tested. The simplest model is in the form of a "hot box" or chamber, which is heat-insulated on the bottom and sides and covered on the top with a twin layer of glass. In order to increase the amount of solar radiation entering the cavity of the box, the sides are equipped with flaps, the inner surface of which has a covering of foil or some other highly reflective material.

Another very common design has as its major component a parabolic reflector, usually of electropolished aluminium, which focuses the rays of the sun on the surface of the heat-receiver (the bottom of a pot, frying pan, tea kettle etc.). The unit is aligned on the sun periodically and by hand (every 10-15 minutes). In Uzbekistan, as tests have shown, a cooking unit of this kind, with a reflector diameter of 1.5 m, permits annual savings of 0.45 e.f.t., which converted to firewood represents about one tonne. Under Afghan conditions, this figure should average somewhat higher. Given the approximate cost of about $300 for such a cooker and a firewood price of 7 afghanis per kg, the unit would pay for itself in only two to two and a half years.

8/ The letters e.f.t. stand for equivalent fuel tonne - i.e., the quantity of fuel equivalent to 7 million kilocalories.

D. The use of solar energy to provide hot water for industrial production processes

Flat solar collectors, the production technology for which is very familiar at the present time, can be successfully used to deliver hot water for low-potential (to 100° C) industrial processes; there are quite a few processes of this kind in, for example, the food industry (pasteurization, bleaching and others). A great deal of heat is also consumed in the washing of glass packaging. On the whole, specialists have estimated the proportion of low-potential heat in the Afghan food industry at about 60 per cent. Since, as indicated above, the total consumption of fuel in the food industry amounts to 12,000 tonnes of coal, some 3,500 tonnes could be saved by introducing flat solar collectors.

In the textile industry, only 10 per cent of the heat consumed is at a temperature of below 80° C. Accordingly, the solar heating of water in the Afghan textile industry, which consumes about three times more fuel than the food industry, will permit savings of only 2,000 tonnes of coal.

Thus, the use of solar heat in Afghan industry will necessarily be on a smaller scale than in the community-household sector, but nevertheless here too will permit tangible savings of fuel.

E. The agricultural use of solar energy

Solar energy can be used in agriculture for the drying of fruits and vegetables - grapes, apricots, figs, onions, tomatoes and the like. At present, private companies in Afghanistan are processing about 40,000 tonnes of raisins, the grapes being dried by the peasants in the natural way and the companies buying up the dried product. The use of chamber-type solar driers makes it possible to reduce the drying time by a factor of 2-3, while continuing to ensure a final product of excellent quality.

The problem of the agricultural use of solar energy should be viewed in close connection with the general standard of living of the rural population. For the time being, the low wages paid the peasants are not conducive to the application of solar engineering in this sector. In the future, as the level of agriculture in Afghanistan is improved and more land is brought under cultivation, the use of solar energy for the drying of agricultural products may become of more immediate interest.

V. CONCLUSIONS

1. At present, no work is being conducted in Afghanistan in connection with the use of solar energy in the national economy, and there are no specialists capable of conducting this work.

2. There are at least four factors which favour the extensive practical use of solar energy in Afghanistan, namely:

2.1 The severe shortage of traditional fuel and energy resources, especially in the community-household sector of the economy, and the unlikelihood that the fuel deficit will lessen in the immediate future.

2.2 The predominance of scattered small-scale energy consumers and the impossibility of providing them with energy on a centralized basis.

2.3 The objective difficulties in organizing fuel deliveries to particular regions of the country.

2.4 The existence, over a considerable portion of the national territory, of favourable climatic and actinometric conditions.

3. In Afghanistan the following applications of solar energy are economically justified, technically feasible, and practically meaningful:

- The heating of water for household needs and for technological processes in industry;
- The heating of dwelling houses of limited size;
- The cooking of food.

The capital costs of the corresponding solar systems can be recouped, in the form of fuel savings, within periods of time substantially shorter than the life-time of the systems themselves.

VI. RECOMMENDATIONS (regarding further work in connection with the use of solar energy in Afghanistan)

1. Using UNDP funds, five or six Afghan specialists (in physics, mechanics, architecture and building, heating and ventilation, and economics) should be sent in 1982-1983 to research centres or laboratories in Australia, India, Italy, the USSR and/or Romania for one year of training in the area of solar heating.

2. Both a scientific research and a planning organization should be established in Afghanistan to provide the basis for future work in the use of solar energy for heating. One of these organizations might be the Kabul Central Institute for City and Building Planning.

3. A solar energy department (laboratory) should be set up at one of the base organizations in 1983; this department should be equipped by drawing on UNDP funds. Through UNIDO channels, a specialist in solar heating from one of the countries mentioned in point 1 should be recruited for two years with the assignment of organizing and directing this department.

4. A study should be prepared in 1982-1983 on the possibility of organizing, at some time in the future, the manufacture of the equipment for solar heating systems at the Jangalak plant in Kabul.

5. A proposal should be submitted to UNDP for a project involving the establishment in Afghanistan, in 1984-1986, of an enterprise to manufacture equipment for solar heating systems (solar collectors, storage tanks, heat-exchangers, solar cookers etc.).

VII. REFERENCES

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ANNEX O

List of persons with whom the author discussed the problems connected with the use of solar energy in Afghanistan and to whom he wishes to express his sincere gratitude

1.	M.G. Pahimi 1/	Deputy Minister of Mining and Industry
2.	H.A. Taieb	Deputy Minister of Public Works
3.	A.T. Barak	Minister of Labour
4.	A. Kavish	President of the Department of Energy, State Planning Committee
5.	D. Kazem	President of the Department of External Relations, State Planning Committee
6.	D. Surosh	General President, Kabul Central Institute of City and Building Planning
7.	S.S. Housain	President, Kabul Central Institute of Building and City Planning
8.	M.K. Azimi	President, "Kabulproject" Institute
9.	A.L. Nurzad	President, Kabul House-Building Industrial Group
10.	N.M. Armon	President, Institute of Meteorology
11.	S.A. Ebodi	Chief Director, Department of Energy, State Planning Committee
12.	A.S. Satorzai	Director, Department of Energy, State Planning Committee
13.	A.K. Samimi	Chief Director, Department of Technical and Economic Studies, Ministry of Mining and Industry.

1/ Translator's note: All names have been reconstructed from the Russian spelling.

ANNEX I

Table 1. Production of energy resources in Afghanistan

	Unit of measurement	1976/1977	1977/1978	1978/1979	1979/1980	1980/1981
Natural gas	Millions of m^3	2 641	2 548	2 461	2 330	2 790
Crude oil	Thousands of tonnes	13.0	13.1	14.0	16.0	8.3
Coal	Thousands of tonnes	161	170	218	130	119
Electricity	Millions of kW/h	712	776	853	916	910

ANNEX III

Table 1. Average monthly and annual air temperature values, °C

Meteorological station	Altitude of station in metres	January	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Mean annual value
Faizabad	1 200	0.1	2.2	7.8	13.0	16.5	23.8	26.4	25.7	20.0	13.8	7.5	2.4	13.3
Kunduz	433	2.1	5.3	10.6	16.4	22.2	28.7	31.3	29.2	23.5	16.4	8.5	3.9	16.5
Mazar-i-Sharif	378	2.5	5.7	10.6	16.8	23.7	28.8	32.0	29.9	23.8	16.4	8.9	5.4	17.0
Shibarghan	360	2.3	5.2	10.5	15.9	22.2	28.2	30.1	27.9	23.6	15.9	9.9	4.9	16.4
Darlamon (Kabul)	1 790	- 3.2	- 3.0	5.6	12.9	16.3	20.9	23.6	22.2	17.8	11.7	5.3	0.9	10.9
Logar	1 935	- 7.8	- 7.1	6.9	13.1	16.7	22.7	25.0	24.7	19.1	11.9	4.5	- 1.0	10.7
Gardiz	2 350	- 5.6	- 3.7	3.8	9.7	14.8	19.8	22.4	22.1	16.9	9.7	4.0	- 2.1	9.3
Ghazni	2 183	- 6.1	- 3.9	4.3	10.4	15.9	21.1	22.9	21.9	16.4	9.9	3.8	- 2.3	9.5
Laghman	770	7.2	9.8	14.6	18.6	24.5	30.8	31.3	29.9	26.0	20.4	13.5	8.1	19.6
Jalalabad	580	8.4	11.0	16.7	21.9	27.6	32.6	32.9	32.1	28.2	22.6	15.2	9.3	21.5
Khost	1 146	4.8	7.5	12.4	16.9	22.2	28.2	27.5	26.5	23.4	17.8	10.6	5.8	17.0
Kalat	1 565	- 0.8	1.7	9.4	14.8	19.9	25.5	27.7	25.9	20.0	14.4	7.9	3.1	14.1
Kandahar	1 010	5.1	8.3	14.5	19.3	24.8	29.4	31.8	29.1	23.2	17.4	10.5	6.3	19.3
Lashkar Gah	780	6.4	10.0	15.8	20.8	26.6	30.9	32.5	29.8	24.4	18.4	11.4	6.9	19.5
Farah	660	6.7	8.8	15.8	19.8	25.7	31.2	33.6	31.4	25.8	19.2	11.5	7.3	19.7

Note: The data for all the meteorological stations with the exception of Darlamon are taken from Ref. 1. The data for the Darlamon station were obtained directly from the Kabul Institute of Meteorology and are mean values for the period 1971-1980.

ANNEX III

Table 2. Average monthly and annual number of hours of sunshine (numerator); its duration as a percentage of the possible total (denominator).

Meteorological station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Faizabad	121/40	126/41	132/36	184/47	262/61	299/69	293/66	306/74	271/73	223/64	183/60	134/44	2534/57
Kunduz	108	130	154	193	255	320	329	333	301	226	174	115	2638
Mazar-i-Sharif	128/42	127/41	140/40	183/47	311/72	357/83	357/81	329/79	285/77	245/71	169/56	146/49	2777/62
Shibarghan	89	129	135	180	302	358	380	361	310	218	173	122	2757
Kabul	174/56	175/56	186/50	215/55	309/71	355/82	356/81	344/83	298/81	284/81	241/78	190/62	3127/71
Logar	150	149	225	252	280	339	371	351	317	274	208	161	3077
Gardiz	189	158	231	233	320	350	354	338	334	305	270	197	3279
Ghazni	197	191	243	256	296	349	333	350	332	282	239	203	3271
Laghman	191	164	201	228	295	350	341	307	314	270	242	155	3058
Jalalabad	182/58	186/59	204/55	202/52	289/66	334/77	336/76	304/73	292/79	268/77	208/67	197/64	3002/68
Khost	230/73	195/63	233/63	219/56	294/69	299/70	261/60	253/61	273/74	277/79	243/77	202/66	2979/67
Kalat	183	182	236	277	324	360	346	330	326	300	253	214	3331
Kandahar	202/63	177/56	247/67	235/61	359/85	382/90	364/85	360/88	326/88	314/89	265/84	241/76	3472/79
Lashkar Gah	204	178	267	251	327	291	320	345	328	270	259	209	3247
Farah	215/68	195/62	228/62	247/64	311/73	327/77	322/74	333/81	316/86	283/81	232/74	207/66	3216/72

Note: Data taken from Ref. 1.

ANNEX III

Table 3. Daily amount of total (numerator) and diffuse (denominator) solar radiation incident to the horizontal surface (kcal/m^2 day) in Darlamon (Kabul). Average values taken over five years (1974-1978). For the sake of comparison the table includes total radiation data for other locations.

Meteorological station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual total Gcal/m^2 year
Darlamon (Kabul)	2432/752	3321/1014	4345/1143	4830/1636	6197/1355	7063/1365	6752/1462	6097/1398	5277/1238	4255/871	3050/661	2235/708	1.70/0.414
Tashkent (USSR)	1330	1950	2770	3920	5290	6130	6320	5640	4560	2840	1800	1230	1.33
Fresno (California, USA)	1860	2960	4380	5450	6370	6970	6680	6060	5030	3750	2410	1600	1.63
Jerusalem	2900	3610	4560	5860	6740	7370	7230	6750	5790	4540	3220	2620	1.86

Note: The data for the meteorological station Darlamon are taken from Ref. 2; the remaining data are from Ref. 4.

ANNEX III

Table 4. Maximum wind velocity values (m/s) and its main directions

Meteorological station	Maximum wind velocity, m/s	Main direction
Chardara-Kunduz	18.0	W
Baghlan	24.0	N
Kabul	30.0	N
Ghaziabad	26.0	E
Sarde Ghazni	29.0	W
Darweshan	25.0	N-W
Herat	34.0	E
Mazar-i-Sharif	30.0	W
Kandahar	28.0	E
Jalalabad	30.0	W
Sharak	30.0	S

Note: The data in this table were obtained from the Kabul Institute of Meteorology.

ANNEX IV A

Expenditure on the manufacture of a solar thermosiphon water-heating facility under Afghanistan conditions

(based on information relating to February 1982)

1. List of the basic equipment of the facility.

1.1 Flat-plate solar collectors with a total surface area of 5.6 m^2 (8 modules of 0.7 m^2 each);

1.2 400-litre storage tank with heat insulation;

1.3 Bearing parts, connecting pipes, fittings.

2. Features of the basic equipment.

2.1 Solar collector

2.1.1 Absorbing panel - steel sheet painted black with a surface area of 600 x 1,200 mm and a thickness of 1.0 mm. A steel coil pipe (diameter 1 inch) is attached to the panel for passage of the heat transfer agent;

2.1.2 Casing: side walls made of wooden boards 20 mm thick; Base - steel sheet, 0.8-1.0 mm thick;

2.1.3 Glass layer - single (normal window glass, 3 mm thick);

2.1.4 Heat insulation - felt (or slag cotton), 50 mm thick;

2.2 Storage tank

Two standard steel vats for petroleum products, each with a volume of 200 litres (see also point 2.1.4).

3. Expenditure on solar water-heating facility (approximate).

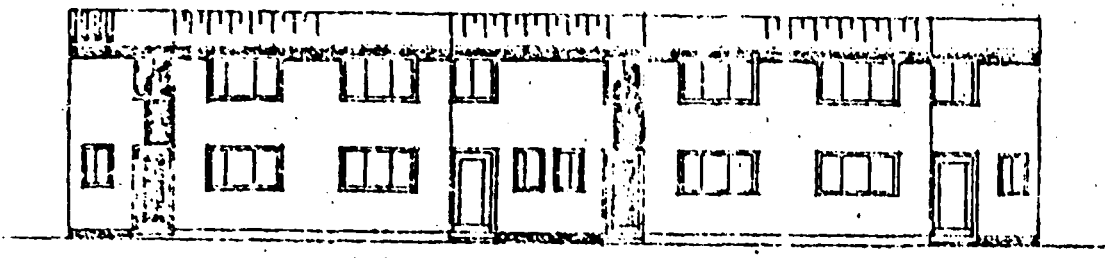
3.1	Solar collectors	
	Materials	12 800 afg.
	Manufacture (in small workshop)	10 400 afg.
3.2	Storage tank	
	Two vats (finished products)	800 afg.
	Manufacture (welding of connecting pipes, heat-insulation work)	600 afg.
3.3	Other equipment	
	(Supports, pipes, fittings)	3 300 afg.
3.4	Assembly of the facility as a whole	2 000 afg.
3.5	Unspecified expenditure	2 500 afg.
	Total	32 400 afg.

or 5,786 afg./m^2

Director of Economics Department (Signed) A.A. Azizi

Certified:

Director of the Department of Technical and Economic Studies,
Ministry of Mining and Industry,
Afghanistan (Signed) A.K. Samimi



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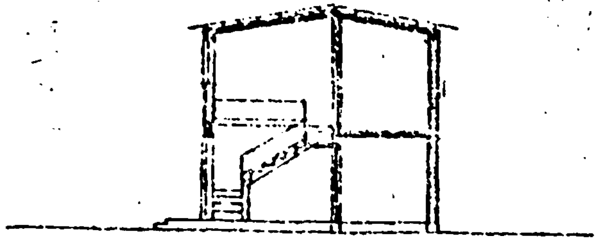
(P) SOUTH ELEVATIO



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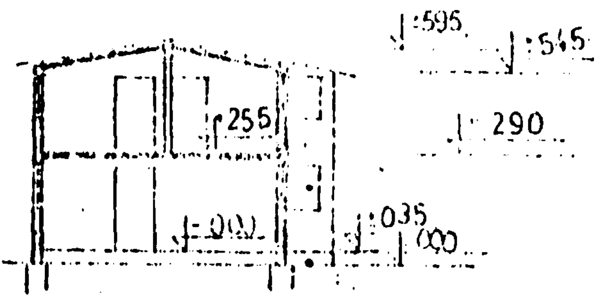

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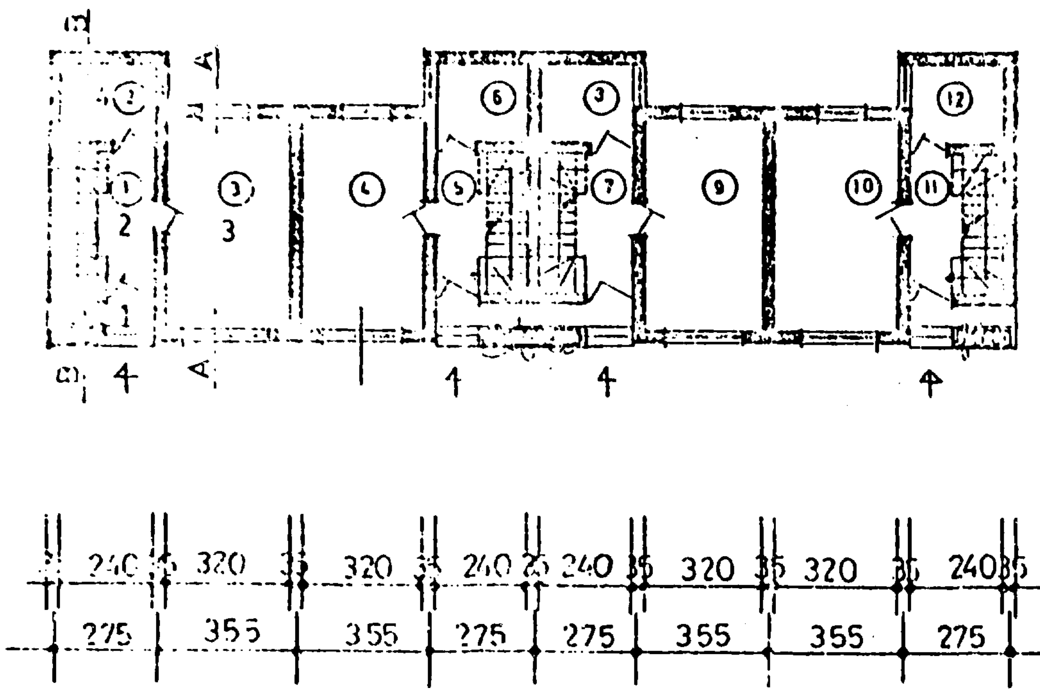


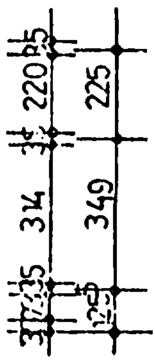
FIRST FLOOR PLAN

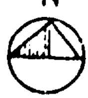
1. TRASS

2. HALL

3. LIVING ROOM

4. KITCHEN





PROJECT : LOW INCOME FAMILIES

DRAWN BY ABDUL WARES

SCALE 1 : 200

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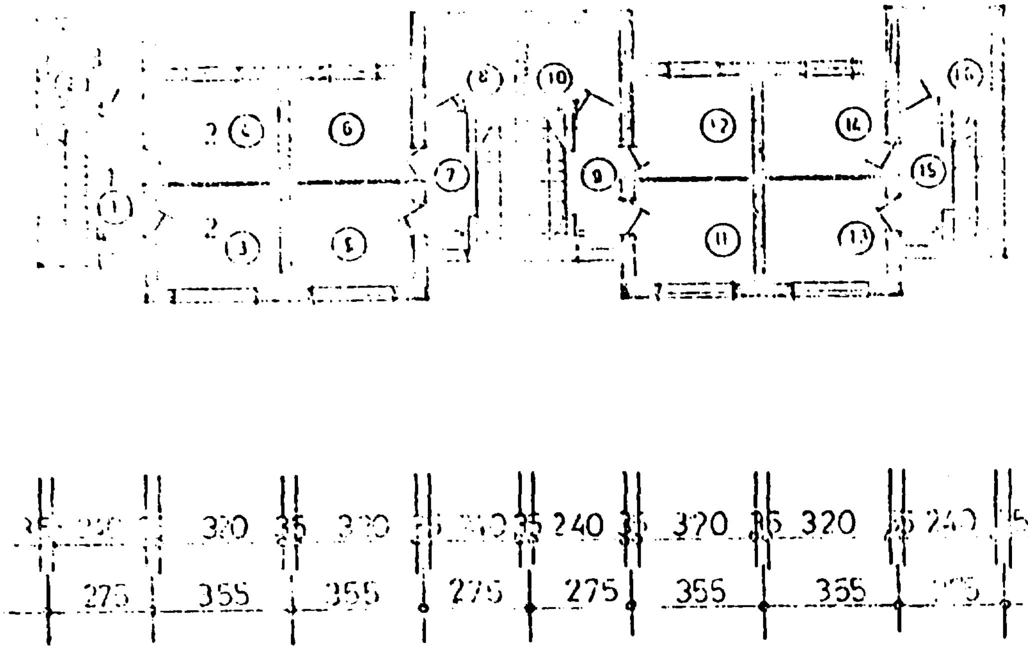


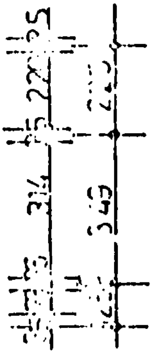
SCOUND: FLOOR PLAN

SCALE : 1:200

1. HALL

2. BEDROOM

3. W.C



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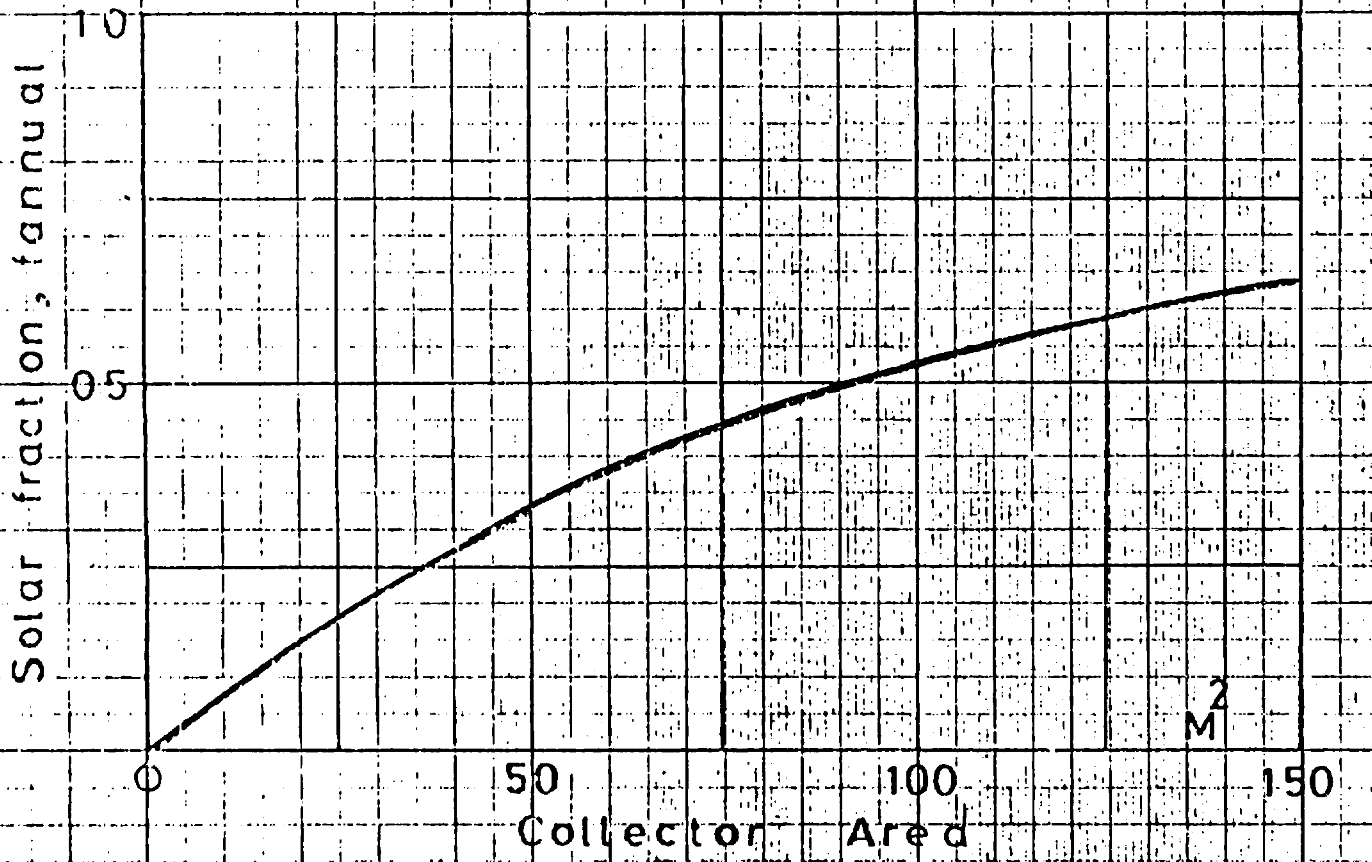

Fig 1 Graph of f annual vs Collector area

Table 1. Calculated performance of the solar heating and hot-water supply system of a two-storey unit of four apartments under conditions obtaining in Kabul

Month	H MJ/m^2 . day	H_t MJ/m^2 . day	Heating load, L_s GJ/month	Hot-water supply load L_w GJ/month	A = 60 m^2		A = 120 m^2		A = 160 m^2	
					f	f.(Ls+Lw)	f	f.(Ls+Lw)	f	f.(Ls+Lw)
January	10.18	17.25	66.0	13.2	0.177	14.0	0.332	26.3	0.423	33.5
February	13.90	19.97	59.1	11.9	0.212	15.0	0.393	27.9	0.497	35.3
March	18.19	21.14	38.7	13.2	0.334	17.3	0.591	30.7	0.725	37.6
April	20.22	18.74	15.4	11.3	0.510	13.6	0.825	22.0	0.951	25.4
May	25.94	20.36	5.3	11.7	0.785	13.3	1.0	17.0	1.0	17.0
June	29.56	21.28	0	11.3	1.0	11.3	1.0	11.3	1.0	11.3
July	28.26	21.20	0	11.7	1.0	11.7	1.0	11.7	1.0	11.7
August	25.52	22.18	0	11.7	1.0	11.7	1.0	11.7	1.0	11.7
September	22.09	23.97	0.6	11.3	1.0	11.9	1.0	11.9	1.0	11.9
October	17.81	24.93	19.6	11.7	0.606	19.0	0.949	29.7	1.0	31.3
November	12.77	21.73	38.3	12.8	0.339	17.3	0.599	30.6	0.734	37.5
December	9.36	16.72	53.3	13.2	0.203	13.5	0.375	24.9	0.476	31.7
Annual values			296.3	145.0	0.384	169.6	0.579	255.7	0.671	295.9

Note: H and H_t are the average monthly values of the daily total solar radiation incident to the horizontal and inclined surfaces respectively.