SOLAR ENERGY AND ITS POSSIBLE ROLE IN AGRICULTURAL PRODUCTION

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Introduction

Throughout history the agricultural sector has relied exclusively on solar energy to provide all its energy requirements, whether directly through the process of photosynthesis, or indirectly through the use of stored solar energy in the form of fossil fuel. Unfortunately, resources of the latter are being depleted at an alarming rate, and man's ingenuity will be heavily taxed to develop and apply alternative energy sources timeously.

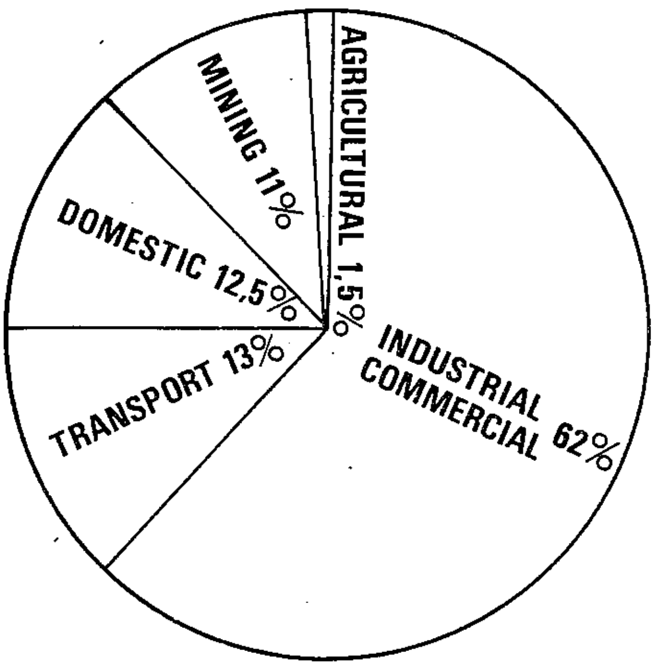
In many instances the technology and hardware needed for the direct use of solar energy is already available. In other instances the technology need only be further tested and refined or optimised, before being generally applied.

The purpose of this paper is to indicate how current solar technology may already be applied beneficially, and to discuss some other areas where further research is urgently needed.

Energy consumption in the agricultural sector

Details of the nett energy consumption in the various sectors of the South African economy are given in Figure 1. It is astonishing that the agricultural sector can produce not only our own domestic agricultural produce requirements, but sufficient for export to constitute one of our largest earners of foreign exchange — all at the cost of only 1,5 per cent of our useful national energy consumption. This most important sector is, unfortunately, extremely vulnerable because of its almost total reliance (98 per cent) on oil.

Oil is used in the agricultural sector as fuel for tractors and other mobile and stationary farm engines and as a source of thermal energy for a multitude of heating applications generally of low temperature, such as crop drying and heating of farm buildings. The production of fuel from organic materials falls outside the NBRI's sphere of activity, and will therefore not be covered in the same depth as thermal applications with which the Institute is involved.



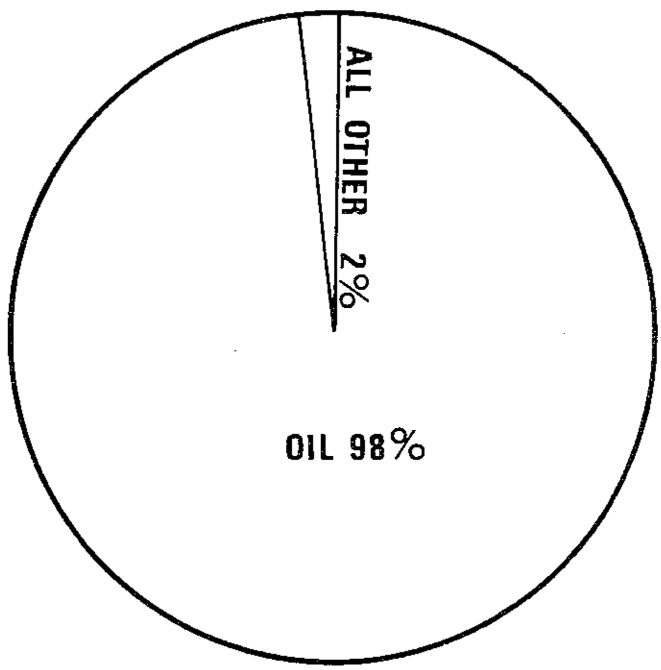


FIG 1 Useful energy consumption by various sectors of the South African economy

Useful energy consumption in the agricultural sector

Characteristics of solar energy

Examination of the information contained in Figure 2 immediately indicates the two major limitations of terrestrial solar energy; namely its low concentration and variable and discontinuous nature.

Regarding concentration, a kilogram of coal has about the same energy content (20 to 30 megajoules) as the amount of solar radiation intercepted by a horizontal surface 1 m^2 in area during an entire sunny summer's day in Durban. Large surface areas of fairly expensive collectors are therefore required to absorb useful amounts of energy. Solar energy is thus more cost effective for low temperature applications than for, say, power generation. However, despite the apparent low concentration of solar energy, one should bear in mind that South Africa is blessed with receiving average solar radiation intensities that are among the highest in the world, as shown in Figure 4. The phrase 'sunny South Africa' is no misnomer.

The annual amount of solar radiation intercepted by a horizontal surface of only 14,5 x 14,5 kilometres in extent in the Durban area is equivalent to our entire nett national annual energy consumption.

Turning now to its variable nature, it should be noted that seasonal fluctuations can, to a large extent, be evened out by inclining the irradiated surface of the collector at some optimum angle as shown in Figure 3. The optimum angle for year round absorption is approximately equal to the latitude of the site plus 10°. More information in this connection is contained in another NBRI publication*.

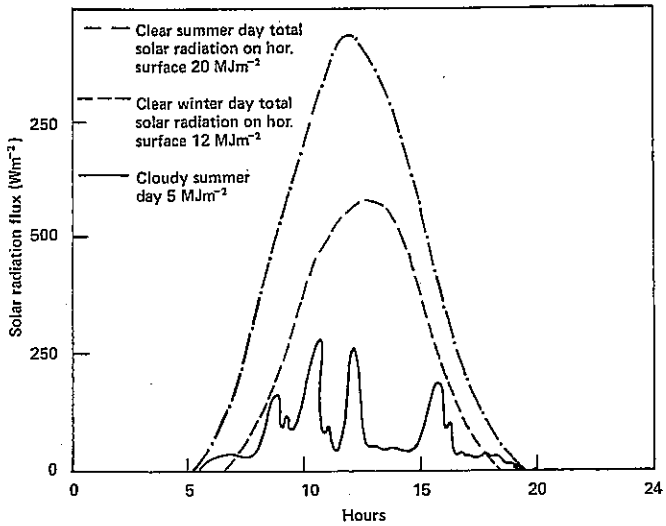


FIG 2 *Total solar radiation on a horizontal surface versus time for clear summer and winter and for cloudy weather conditions in the Durban area*

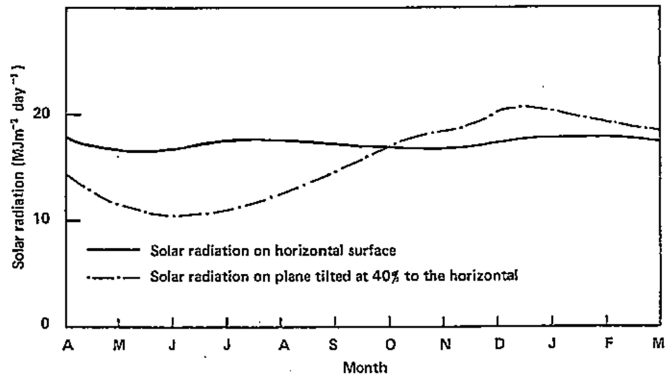


FIG 3 *Annual variation of total daily solar radiation on horizontal and tilted surfaces in the Durban area*

FIG 4 *Generalized isolines of global radiation GJ / m^2*

Johnson, M. Availability of solar radiation in South Africa. NBRI information sheet X/BOU 2/40

Daily variations can only be evened out by incorporating some means of storing the energy available during peak radiation periods for later use. This generally adds significantly to the cost of a solar installation. Common storage media are rock, water and phase-change materials.

Methods of collecting solar energy for use in low temperature agricultural heating applications

The following methods of collecting solar energy and transforming it into sensible heat will be dealt with:

i Solar water collectors
ii Solar air collectors
iii Solar ponds

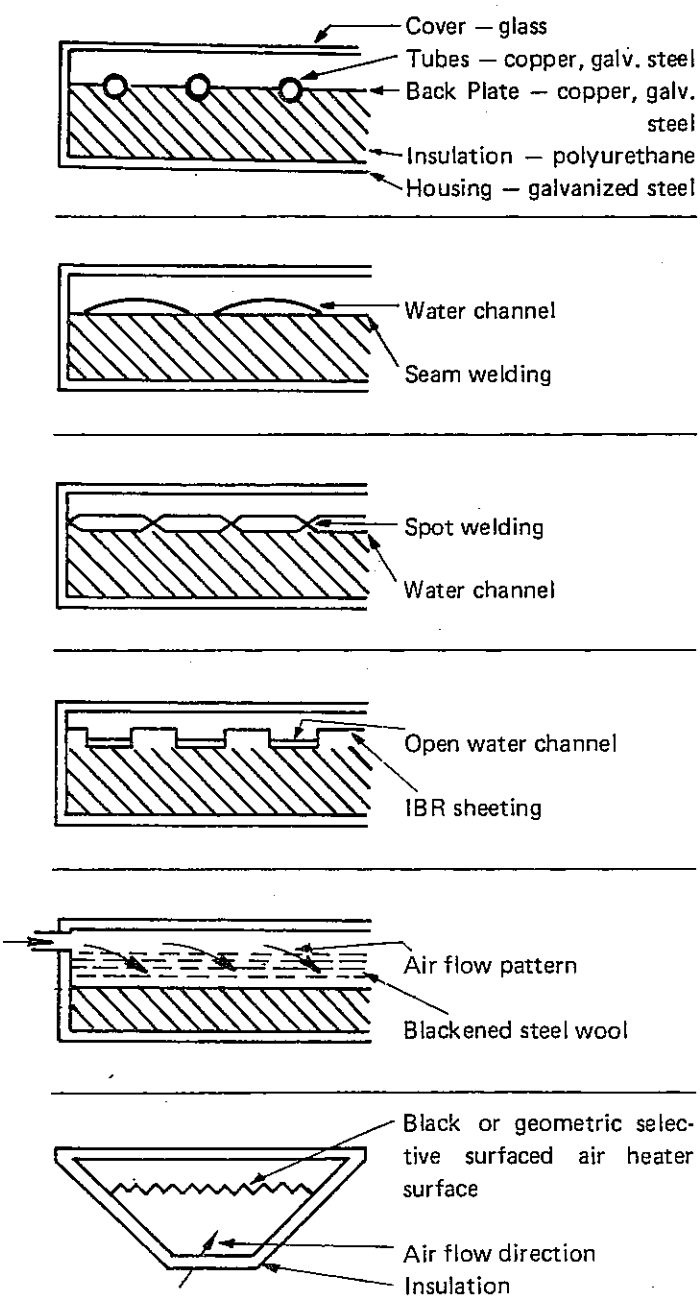


FIG 5 Sections through various types of solar water and air heaters

Solar water collectors

Solar water collectors generally consist of a heat exchanger plate or absorber, an insulated housing and a transparent cover. The function of the absorber, as its name implies, is to absorb as much as possible of the solar radiation intercepted by it, and transfer it in the form of heat to the working fluid (usually water) flowing through it. The absorber is placed on top of a 25 mm thick layer of polyurethane foam insulation, or its equivalent, and house within a waterproof tray which is covered with 4 mm thick window glass, or some other suitable transparent material. The purpose of the insulation is to minimize heat losses from the bottom and sides of the absorber. The transparent cover acts as a 'one-way valve' to solar radiation, in that it allows most of the short-wave radiation (80 to 90 per cent) to pass through it, but is opaque to the long-wave re-radiation from the absorber surface. The irradiated surface of the absorber is generally painted matt black so as to maximize absorption of solar radiation. Alternatively, the absorber may be treated with a selective coating, which is highly absorbtive for short-wave radiation, but emits very little long wave-length re-radiation from the absorber surface. These latter surface coatings are more expensive than matt black painted surfaces, unless very large production volumes are involved. Sections through some solar air and water collector designs, including the more popular materials used, are indicated in Figure 5.

Solar air collectors

The primary difference between solar air and water heaters is in the design and material used in the actual heat exchanger or absorber unit. In the case of an air heater the absorber generally consists of a shallow air duct, usually provided with some means of increasing air turbulence, and therefore heat transfer, as the air passes through the duct. Otherwise both air and water collectors are very similar (Figure 5).

Air collectors have the following significant advantages over water collectors:

a Absorbers need not be absolutely air-tight.

b Absorbers need not be made of corrosion resistant material.

c Far lighter materials and construction techniques can be employed for the entire air collector.

d Liming-up of the absorber does not constitute a problem.

e Freezing protection is unnecessary.

f Boil-out conditions do not arise.

g Air collectors can be expected to have a longer trouble-free life expectancy than water collectors.

Air collectors generally cost less than water collectors but due to the increased cost of the associated equipment that goes with the air system (blowers, ducts, dampers, air handling modules, etc), the overall costs of air and water systems are generally on a par.

Combination solar water/air heating systems

In many situations combination water/air heating systems are needed. These can be constructed very simply by incorporating water-to-air or air-to-water heat exchangers, as the case may be, in the circulation system.

Solar ponds

The solar pond operates on an entirely different principle. It consists of a shallow pond, approximately one metre deep, filled with a salt solution. The density of the solution increases from top to bottom, being almost salt free at the top and saturated at the bottom. The function of the density gradient is to counteract the natural convection of the solution, so that instead of the hottest water rising to the top, it remains at the bottom of the pond. Heat is then extracted by means of a heat exchanger coil situated on the floor of the pond (Figure 6). While water temperatures at the top are in the region of 30°C, those at the bottom can be as high as 80 or 90°C. Though efficiency of solar ponds operating at this temperature is only about 20 per cent, their construction costs are substantially less than for air or water collectors (approximately R20 m^{-2}). Their major advantage for agricultural applications is considered to be their high termal inertia, which means that they can supply a heat output for weeks rather than days, and therefore bridge fairly extended cloudy periods. They may, therefore, have considerable application, for example, in the heating of greenhouses and crop drying. Much work has been done in Israel using solar ponds to provide the energy for desalinating sea water.

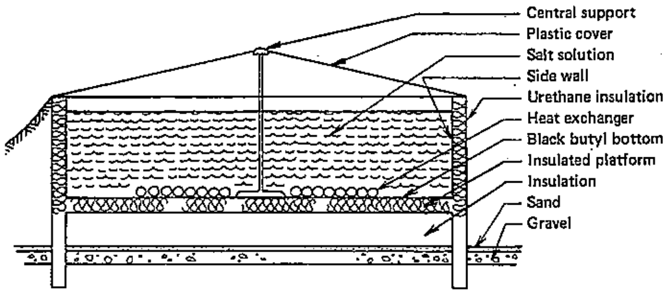


FIG 6 Section through a solar pond

Sensible and latent heat storage systems

Having collected the solar radiation and transferred the energy in the form of sensible heat to the working fluid circulating through the absorber, it is often necessary to store the heat for use at night or during cloudy weather conditions. As mentioned previously, the most common heat storage media are gravel beds, water and phase-change materials. Reversible chemical reactions are also being looked into as they, too, offer possibilities for storing heat.

Process water heating applications

Having dealt briefly with methods of collecting and storing solar energy in the form of heat, the following section deals with a few of the innumerable low temperature uses of this heat in the agricultural sector. The examples will be treated in order of increasing process temperature requirements.

Fish breeding (less than 30°C)

The NBRI has been asked on a number of occasions for assistance in the use of solar energy for heating water on fish breeding farms. It is estimated that the industry produces 100 tons of carp alone, annually. The temperature of water, in bream and carp tanks for example, should not drop below 25°C if optimum growth rates are to be maintained through the year. In this specific low temperature application, plastic collectors without back insulation or glass covers can be used to absorb the solar radiation. Tests conducted by the NBRI indicate that such collectors can achieve solar energy to a heat-conversion efficiency of over 90 per cent at midday during warm winter days. These collectors are marketed for, approximately, R30 per square metre; this means that they provide low grade heat for a cost of about 0,6 cents per kilowatt hour. Surely this must be the cheapest source of heat available.

Domestic hot water heating (less than 45°C)

The provision of hot water for ablution purposes is an obvious immediate application of solar energy, for which all the necessary technology is available, and equipment is marketed on a commercial scale. Further information, including lists of manufacturers and details for the farmer and other 'do-it-yourself' enthusiasts, is available from the NBRI.*

Costs of solar collectors vary from R55 m^{-2} to R400 m^{-2} depending on the type of system and materials of construction.

It should be noted that domestic water heating accounts for between 40 and 50 per cent of the total energy consumed in the average middle income group South African house. Further, since the domestic sector accounts for about 20 per cent of the total national electricity consumption, the importance of the large scale use of solar energy for domestic water heating cannot be over emphasized.

**BG6 NBRI Introductory Guide to Solar Energy*

Wool and textile industry (50°C)

Hot water for the wool and textile processing industry is needed at temperatures around 50°C. It is estimated that the annual national hot water consumption in this industry alone amounts to 300 megalitres for wool scouring and carbonizing activities, and a further 7 720 megalitres for the finishing and dyeing of wools and textiles. This is approximately equivalent to the hot water consumption of some 90 000 middle income group South African homes, or 1 006 x 10^3 GJ per annum in terms of energy consumption.

Dairy farming (30 to 70°C)

Large volumes of hot water are needed to perform the various ablution and sterilizing functions on dairy farms. Approximately 550 litres of lukewarm water at temperatures of less than 30°C are required to wash down the udder before and after milking and for general ablution purposes in a typical milking parlour designed to handle 100 cows daily. A further 600 litres at 77°C is needed to sterilize milk-handling equipment on an installation of similar size. The national daily milk production is approximately 4,9 megalitres per day and yield per cow is estimated at about 10,4 litres cow^{-1} day^{-1}. Based on the above figures approximately 808 x 10^3 MJ of energy would be needed daily to provide the hot water requirements of dairy farms throughout the country.

Based on the experience gained from domestic hot water heating, it is estimated that solar energy could effectively supply between 60 and 75 per cent of these hot water requirements.

Air process heating applications

The main agricultural applications of heated air would appear to be for crop drying. Substantial progress has already been made in Rhodesia in this area. For example, at least twenty tobacco farmers use solar energy to preheat the air used for drying tobacco in their tunnel dryers, with a resultant fuel cost saving of about 15 per cent. Other farmers have for many years successfully used so called 'barn dryers' for drying crops such as lucerne, maize and onions.

Solar crop drying

There are many types of dryers, but most fall into either passive or active dryer categories. In passive systems the crop is exposed to the sun, either in the field before harvest or on some form of perforated tray after harvest where it is again left exposed to the sun and dried until the desired moisture content is reached. Active systems are those in which the crop is harvested and placed in a perforated bin where hot air is blown through the crop at a pre-determined velocity and temperature until the desired moisture content is obtained.

Passive solar dryers — cabinet or hot-box dryer

A cabinet dryer of the type illustrated in Figure 7 generally reduces the drying time of fruit and vegetables to about half that normally achieved in the open.

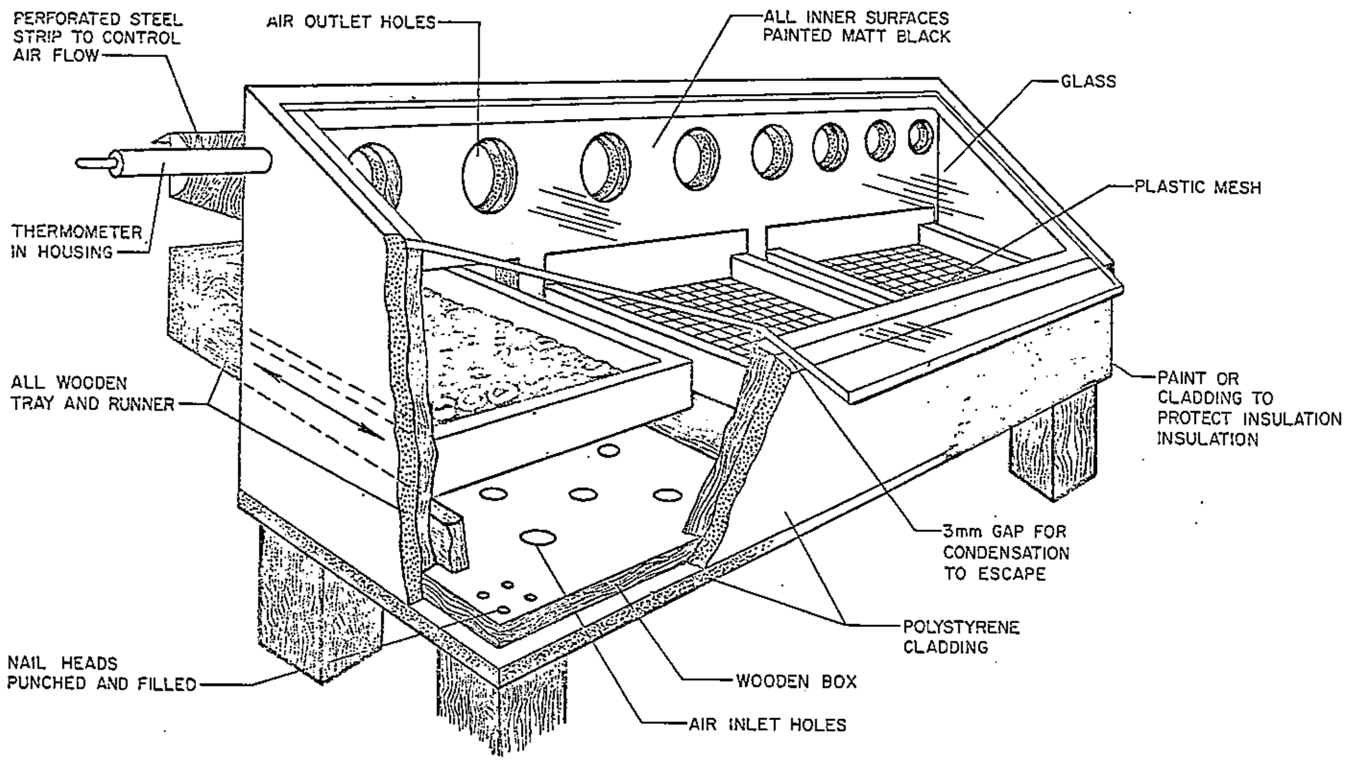


FIG 7 Hot-box type fruit and vegetable drier

TABLE 1 *Climatic data for four centres in South Africa, at the five per cent probability level (from Van Deventer, 1971)*

			Hour of day																							
Station	Element	Season	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Bloemfontein	DB	Summer	18,3	17,6	17,0	16,4	15,9	16,2	19,0	21,6	24,3	26,6	28,4	29,9	30,0	31,5	31,6	31,1	30,4	29,2	26,7	23,5	22,0	20,8	20,2	19,5
	RH		63,4	65,0	72,4	78,0	77,6	79,3	66,5	55,9	48,6	43,3	37,6	31,3	28,7	27,0	25,2	26,4	30,2	32,0	35,1	33,2	40,4	36,7	44,4	51,4
	SR							48	245	472	653	879	969	1 069	1 039	957	754	513	357	199	47					
	DB	Winter	–0,4	–1,2	–1,7	–2,2	–2,6	–3,0	–3,1	–0,9	3,8	6,8	9,0	10,5	11,7	12,6	13,0	12,9	11,7	7,5	4,9	3,3	2,7	2,0	1,6	1,2
	RH		65,0	70,1	68,4	72,8	75,7	80,7	83,4	77,0	64,5	54,0	46,7	36,6	31,0	26,8	27,3	27,7	31,3	36,5	46,0	50,5	58,6	58,8	61,6	60,2
	SR								23	118	306	471	603	700	741	707	570	382	124	12						
Durban	DB	Summer	21,9	21,5	21,2	21,0	20,8	21,2	22,8	24,5	26,3	27,1	27,6	28,0	28,0	27,9	27,4	26,6	25,9	25,2	24,5	24,2	23,8	23,4	23,0	22,6
	RH		84,7	90,2	89,8	90,4	90,8	88,7	83,3	75,0	70,0	69,2	67,0	67,6	67,6	70,5	72,1	74,6	78,3	80,4	84,3	85,7	85,9	84,8	87,1	86,8
	SR							38	151	360	557	742	914	984	969	847	654	438	234	97	22					
	DB	Winter	8,5	8,0	7,5	6,8	6,2	6,2	5,9	8,5	15,1	19,9	22,4	23,2	23,2	23,0	22,6	21,7	20,0	16,6	14,8	13,7	12,7	12,0	11,6	11,4
	RH		90,0	87,4	89,6	91,4	90,8	90,2	89,6	84,1	59,1	45,1	39,0	39,1	43,6	49,1	50,0	60,2	58,8	70,3	78,0	80,0	78,0	71,0	77,0	87,5
	SR								12	68	238	386	493	543	560	511	387	216	77							
George	DB	Summer	15,9	15,6	15,5	15,2	15,3	15,5	17,8	20,3	22,9	24,8	26,0	26,7	27,0	27,2	26,8	26,0	24,9	23,5	22,1	20,8	19,7	19,1	18,5	18,1
	RH		94,6	93,7	93,9	95,8	91,6	95,7	79,1	75,8	67,7	57,9	62,4	59,2	65,6	60,4	64,0	64,9	70,8	73,9	81,8	88,1	93,8	93,2	92,1	92,4
	SR							50	220	454	659	835	910	1 037	1 046	932	837	655	443	218	51					
	DB	Winter	5,7	5,4	5,0	5,2	5,4	5,7	5,6	6,8	10,6	12,9	14,4	15,3	15,7	15,8	15,6	15,0	13,7	11,4	9,6	8,8	8,4	8,2	7,9	7,8
	RH		86,7	86,8	85,8	84,7	81,9	81,4	80,4	79,5	71,8	68,2	61,2	57,3	57,6	60,6	60,8	63,5	73,4	79,6	91,0	87,1	84,0	84,4	86,0	79,9
	SR								31	127	225	420	548	581	620	486	385	208	89							
Jan Smuts	DB	Summer	17,7	17,0	16,5	16,0	15,5	15,6	17,2	19,4	21,8	23,5	24,9	26,0	27,0	27,5	27,4	26,8	26,2	25,0	23,1	21,4	20,6	19,7	18,8	17,9
	RH		72,6	79,4	73,5	78,6	62,0	78,0	75,9	64,9	58,6	48,6	47,8	44,7	38,7	36,8	36,7	38,5	44,7	46,1	56,2	52,4	64,4	58,2	67,4	69,9
	SR							182	431	664	858	1 004	1 074	1 071	1 000	868	663	437	186	26						
	DB	Winter	2,9	2,4	1,9	1,4	1,0	0,7	0,5	1,9	4,8	7,1	9,0	10,7	11,9	12,6	13,0	12,8	11,8	9,4	8,0	7,1	6,4	5,7	5,1	4,6
	RH		63,5	72,2	77,5	75,3	78,3	79,8	82,8	69,4	67,6	48,3	41,2	31,0	30,3	34,2	27,5	27,3	23,7	25,8	31,6	45,3	41,9	50,4	50,4	54,4
	SR									137	332	495	723	832	790	645	527	329	179							

DB – Dry bulb temperature in degrees Celsius

RH – Relative humidity in per cent

Active systems — barn dryer

The primary factors influencing the drying rate of crops are the airflow rate and relative humidity, and the crop moisture content and load per unit area of airflow path. In practice, the relative humidity of air to be used for drying purposes should be less than about 60 per cent to dry the crop to a level where it can be safely stored. Examination of the information presented in Table 1 shows that the outdoor relative humidity, particularly at night during the drying period, often exceeds this level. Therefore supplementary heat and heat storage are required if drying is to be sustained over a 24-hour period.

From the psychometric chart for most inland areas in Southern Africa (Figure 8) it can be seen that a temperature rise of less than 10°C would be more than adequate to drop the relative humidity of the air from saturation to below the 60 per cent level.

As mentioned above, since high relative humidities occur at night, some form of heat storage facility is necessary. For farm use the most suitable method of storage would seem to be a rock or gravel bed. Work is currently in progress at the NBRI to establish performance characteristics of rockbeds with respect to rock size, void ratio, airflow rate, heat absorption, etc.

From the foregoing analysis it would appear that the most cost effective approach to solar crop drying may be provided by using an existing, suitably orientated, corrugated iron barn roof that would serve as the absorber of an uncovered collector. The irradiated or exposed surface of the roof should be painted matt black for maximum energy absorption, and a ceiling would need to be installed some 50 to 100 mm below the corrugated iron cladding. Air in the space between ceiling and corrugated iron would be heated by the absorption of solar radiation by the roof and could be circulated by an air blower through the crop. The optimum distance between the corrugated iron and the ceiling would be governed by the length and number of obstructions in the airflow path. Airflow should be at right angles to the corrugations if possible, as the resulting air turbulence can double the rate of heat transfer. In areas with prevailing wind directions the system should preferably be so designed that the general direction of the airflow in the apex of the roof is in the same direction as that of the wind. Alternatively the roof should be well-sealed. A rockbed of appropriate design should be incorporated in the system, between the air collector and the crop to be dryed.

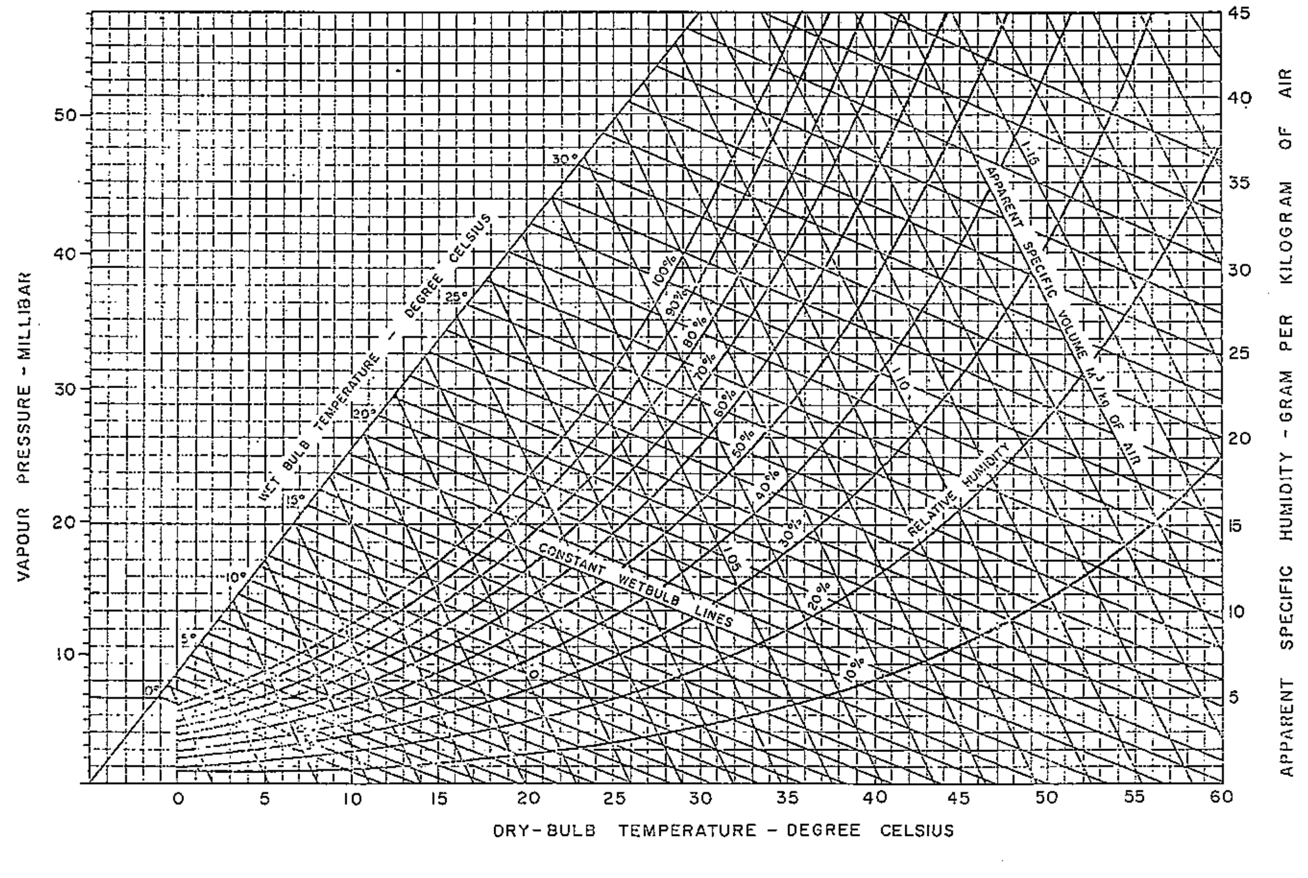


FIG 8 Psychometric chart for atmospheric pressure of 850 millibar

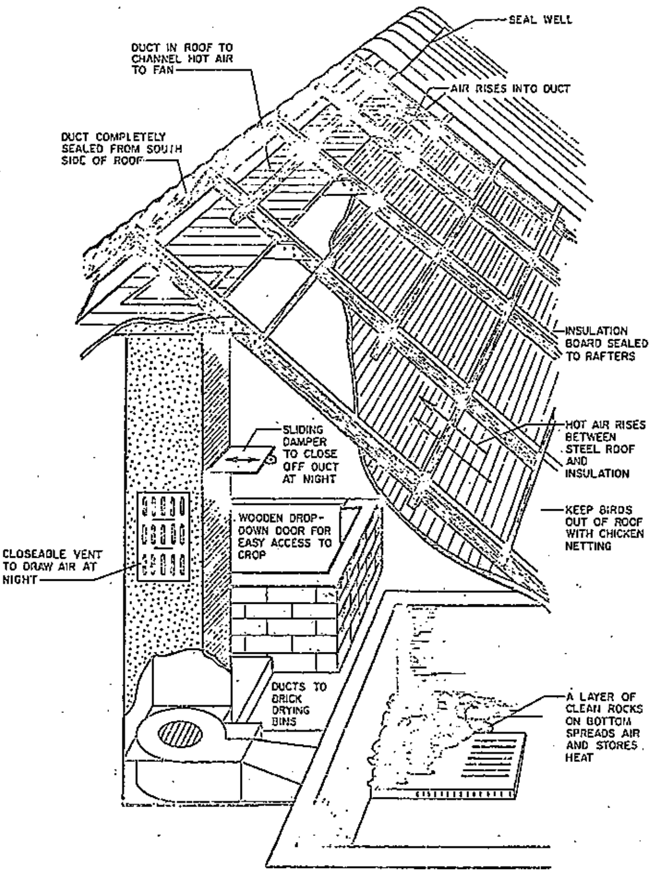


FIG 9

The rockbed should have adequate storage capacity and appropriate heat delivery characteristics so that:

(a) large diurnal temperature fluctuations are eliminated; and

(b) air is delivered to the crop at an elevated temperature, so that a relative humidity of below 60 per cent is maintained throughout the drying cycle.

The system would operate as follows:

During the day air would be drawn from the collector via the rockbed and blown through the crop. At night heat would be extracted from the rockbed and air would be drawn from the interior of the barn, rather than through the collector, which, due to radiant cooling, could be well below ambient air temperature. Such a system is illustrated in Figure 9.

Solar heating of greenhouses and agricultural tunnels

The environmental conditions encountered in greenhouses and tunnels are unique, in that both heating and cooling are often required within the same 24 hours, ie heating during the night and early morning, and cooling during the day. An ideal arrangement would be to store the heat rejected during the day for nighttime heating. Tests along these lines are currently in progress in the United States of America. Hot air is drawn from the greenhouse during the day, and blown through a subfloor rockbed. The aim is to create a situation where the floor temperature reaches its peak temperature 12 hours later than that of the outdoor air.

A second approach capitalises on the fact that plants only use the visible portion of the solar emission spectrum for photosynthesis. The remaining, near infra-red, energy which accounts for 46 per cent of the total radiant energy, can therefore be used for heating without affecting plant growth. The majority of the near infra-red energy can be absorbed in a layer of water only 10 mm deep. If necessary this depth can be reduced by adding copper-chloride ($Cu\ Cl_2$) or suitable dyes to the water. The following procedure could be used to both heat and cool greenhouses. The roof and north-facing wall of the greenhouse could be covered by double-walled transparent sheeting through

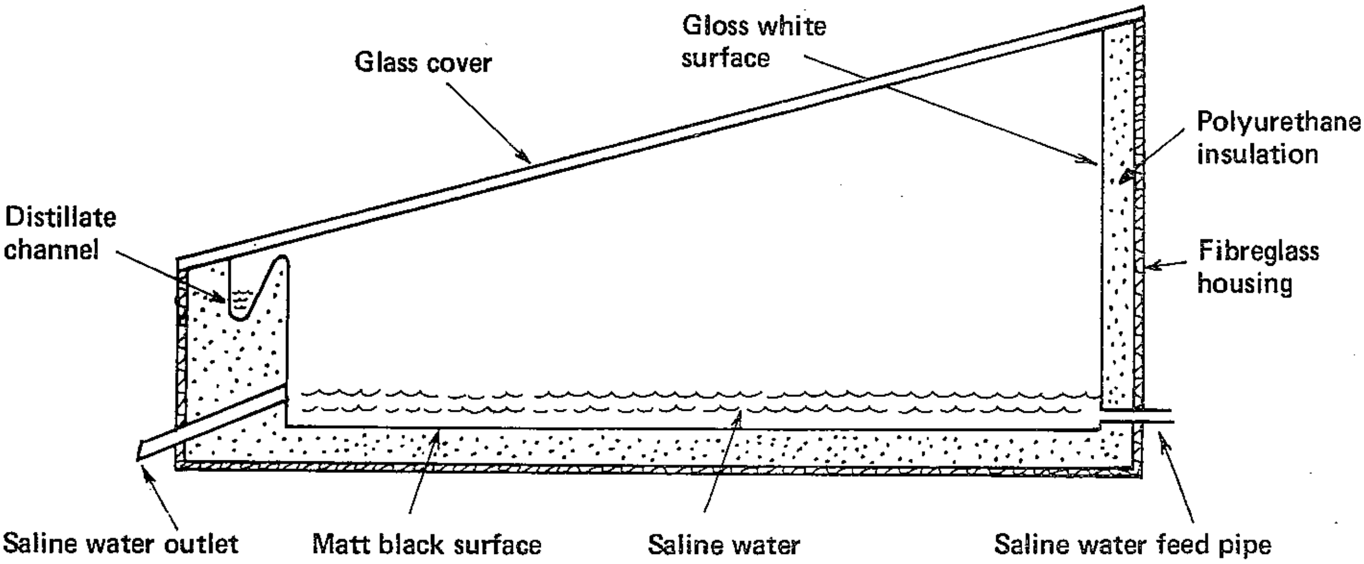


FIG 10 Flat plate solar still

which the water would be circulated during the day. A large percentage of the infra-red radiation would be absorbed in the water before entering the greenhouse where it would normally have caused undesirable over-heating. The heat thus stored in water during the day could then be used to advantage at night, by circulating the warm water through pipes in the greenhouse floor. Water would be drained from the roof and north wall at night, and the resulting air space would substantially improve night heat loss characteristics of a greenhouse. The NBRI is currently evaluating a thin-walled polycarbonate extrusion for this and other purposes.

Solar distillation

Water is often too brackish or polluted to be acceptable for human or animal consumption. This problem can be overcome by means of solar distillation.

A solar still consists essentially of a shallow, well-insulated waterproof tray, with a single sloping glass cover as illustrated in Figure 10. Water in the tray is heated by the sun, vaporizes, and condenses again on coming in contact with the underside of the cool glass cover. Droplets of condensate run down the sloping glass and leave the still via a shallow trough at the lower edge of the glass. Further details are contained in a publication compiled by the Department of Water Affairs.*

Liquid fuels

As mentioned in the introduction, it is in the use of liquid fuels that the farmer is most vulnerable, due to his almost total reliance on imported supplies. In the absence of local oil finds, this situation could still be averted either by increasing our oil from coal production capacity, and/or by using ethynol or methanol produced from organic materials. Scientists in Canada estimate that their total motor fuel requirements could be supplied from waste timber alone. Brazil has embarked on a major research project, aimed at substituting 'home-grown' ethynol produced from sugar cane bagas and cavassa for all imported petroleum by 2000. In South Africa we currently have a surplus of sugar cane. Australia, as early as 1976, announced a similar programme aimed at supplying 13 per cent of her primary energy needs in the form of ethynol by the turn of the century.

South Africa is spending vast sums of money developing Sasol II to reduce our dependence on imported oil. What should be borne in mind is that, irrespective of whether our coal supplies last for 20 or 50 years, they are *finite*, and immediate steps should be taken to make some provision for the future. The Government's current budget for biomass research is, for all practical purposes, nil.

Gaseous fuels

In the past three years China has manufactured 4,3 million biogas plants which convert sewerage, animal dung and agricultural waste to methane gas. Among other applications methane gas is an ideal, non-polluting fuel for stationary engines, and can be used as a source of medium temperature heat for operating freezers and for cooking purposes. The technology is locally available, but only applied in very isolated instances. Besides the methane gas produced in such plants, the waste slurry constitutes an excellent, virtually odourless, fertilizer of extremely high plant-nutrient quality. Further research, public education and some government action appear to be overdue in this area.

Electric power generation

Electric power reticulation from centralized power stations to isolated consumers is extremely expensive. The cost of ESCOM power to the farmer, is therefore, prohibitive in many instances. It is primarily for this reason that electricity constitutes less than two per cent of the energy consumed on farms in general. The running costs of electricity produced from diesel generators are also high and costs will continue to rise in relation to the increasing cost of diesel fuel. Solar energy, in the form of hydro and wind power provides satisfactory solutions in some instances. Research on hydro power generation is being conducted at present by the Division of Agricultural Engineering in Pretoria. However, the approach that may hold the greatest long-term future potential for farmers appears to be provided by photovoltaic cells, commonly known as solar cells.

Photovoltaic cells

The solar cell is a spin-off of space-age technology and provides a means of converting sunlight direct into electricity without any intermediate steps, or generation of heat. The capital cost of cells is still prohibitively expensive. However, the use of solar cells, on farms in particular, may well be an economic proposition within five to ten years, if the current dramatic decrease in the price of cells continues. A concentrating solar cell array currently being installed at the Arkansas community centre will generate 362 kilowatts at a total installed cost of R5 220 per peak kilowatt. It is interesting to note that while the cost of solar cells is now about one-tenth of their cost five years ago, the cost of nuclear power has doubled in the same period.

An interesting development reported by the University of Nebraska is a seven kilowatt pumping station operated off solar cells erected at the university's field laboratory at Mead, Nebraska. The installation supplies some 6,48 megalitres per day to irrigate 82 hectares of maize at the field station.

**Handleiding vir die konstruksie van 'n dubbel skuins dak sondistillasie-eenheid* — Department of Water Affairs (SWA Branch) July, 1973

Conclusion

An attempt has been made to review a few of the innumerable, worthwhile applications of solar energy in the agricultural sector; also to point out those areas where the use of solar energy can reduce this sector's dependence on imported energy sources. The technology for some of these solar applications is already available, and proven; the hardware is already in the market place. In other areas, technology needs only to be further tested and optimized.

Governments in other countries appear to have realized the potential of solar energy as a major source of energy for the future. The United States of America's Department of Energy 1977/78 budget allocation for solar energy research was $389,9 million – a great improvement on the $1,7 million allocated for 1971. The prospects for using solar energy in South Africa are at least equal to, and probably greater than, anywhere else in the world, yet the Government's annual budget for solar energy research amounts to only about R250 000. On a per capita basis, the budget allocation is less than one cent per person as against the more than R1 per person in Israel and R1,20 in the United States of America. The amount spent on agricultural applications of solar energy is for all practical purposes nil.

In the light of the above, South Africa's general inactivity in this field can only be considered short-sighted in the extreme.

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