Introducing Solar Powered Solvent Extraction of Coconut Oil in Panjang Rejo, a Village in Central Java, Indonesia

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ABSTRACT

Oil-extraction of peanut, coconut and oil-containing seeds are generally done by pressing. Presscakes often contain up to 15% residual oil and since for lifestock admixtures 5% oil content is ample, about 10% could still be extracted if an economic way of extraction could be found. Solvent extraction of presscakes containing residual oil has been attempted using a soxhlet modified for solar energy use.

Solar energy falling on a blackened metal box containing the solvent evaporates the solvent. At the upper part of the apparatus condensation takes place and the condensate streams down a column filled with the presscake containing residual oil. The oil-solvent mixture collects in the metal box in which the volatile component is again separated by solar energy leaving a progressively enriched mixture in the metal box. The final product is bled off after overnight standing.

The process is primarily intended for cottage industry in rural surroundings, picking up where the oil-factories leave off. However there is a priori no reason why the process cannot be scaled up.

The laboratory experiment was transferred to a village at the actual site of coconut oil production.

It was found in this particular case that the solar energy device was accepted on the bases of added income because of fuel saved. The fuel saved, in this case charcoal, which was a byproduct of the coconut oil production process could be sold at profit in a nearby town.

From a social and economic point of view careful consideration has to be given to the fact that introduction of a new technology, in this case, solar technology can reduce manpower and is therefore unacceptable in the village context as a whole.

GENERAL GEOGRAPHICAL AND "ENERGY" BACKGROUND

Total land area in Indonesia is 2 million km^2 of which 60% or 120 million hectares is forest land.

The income per capita is US $ 143/year.

Sources of energy are firewood, charcoal, straw, bagasse, coal, gas, oil and hydropower.

Indonesia has known oil reserves of 15 million barrels but an oil production at 1.7 million barrels a day is rapidly diminishing this reserve.

Indonesia is a minor oil producing nation of only 2% of the world crude oil production. Oil exports account for three quarters of the total value of Indonesian exports but domestic oil consumption is increasing at a rate of 14% per year, threatening to make the country a net importer of oil within the next 15 years.

The consumption of firewood in Indonesia has been estimated to be 0.75 m^3 per capita per year in 1970.

With this rate total firewood consumption will be 104 million m^3 in the whole of Indonesia and 64 million m^3 in Java, causing severe deforestation, erosion floods and ecological deterioration (1).

GENERAL OVERVIEW OF ENERGY ALTERNATIVES IN INDONESIA (1)

Indonesia is an archipelago of some 15,000 islands stretched along the from 95°W longitude in the west to 140°W in the east and from 6°N latitude in the north to 11°S in the south with an average yearly insolation of 1946 to 1390 kW/M^2.

The five main islands are, from the West to the East, Sumatra, Kalimantan, Java, Sulawesi and Irian. About 6,000 of the islands are inhabited. Population distribution is very uneven. Of the total population of 142 million in 1978 about 63%, or 89 million, are in the island of Java having an area of only 7% of the country's land area.

A National Energy Seminar held in 1974 by the Indonesian National Committee of the World Energy Conference has projected an electric power demand of 64,000 MW in the year 2000, to be met as follows:

Resource	Capacity (MW)	Percentage
Hydropower	4,000 - 5,000	6 - 8
Oil	12,800 - 39,000	20 - 61
Geothermal energy	500 - 6,000	1 - 9
Coal	8,000 - 16,000	12 - 25
Nuclear energy	15,000 - 25,000	23 - 39
Total	64,000	100

Energy options for Indonesia in the near future are : solar energy, geothermal energy, ethanol from biomass, biogas, and power from associated gas presently flared.

Indonesia may produce ethanol from sugar cane and cassava to economize on its oil consumption.

Indonesia may likewise produce ethanol by fermentation of sago to be harvested from its sago (*Metroxylon* spp.) forests, and by fermentation of toddy from its nipa (*Nipah fructicans*) stands.

Indonesia seems to have some 7.7 million hectares of unexploited sago forests in Irian Jaya with a yearly potential of an estimated 30 million tons of sago or 12 million tons of ethanol.

One hectare of uncultivated nipa forest has a potential yield of 3.4 tons of sugar or 1.3 tons of ethanol. In Sumatra, Kalimantan, and Irian Jaya there seem to exist at least one million hectares of fairly pure nipa stands.

Sago and nipa sugar could also be used as food for humans or feed for cattle. Biogas from digesters of manure and organic waste is a promising alternative. Several digesters have been constructed in villages producing methane for fuel and liquid effluents for fertiliser while cleaning the environment (1).

SOLAR ENERGY INTRODUCTION IN PANJANG REJO, A VILLAGE IN CENTRAL JAVA, SOCIAL AND ECONOMIC BACKGROUND

The village under study, Panjang Rejo in the Grudo region, south of Yogyakarta is a typical central Javanese village with a population of about five hundred families. Each household typically consisting of adults and children with an average of eight to ten people per household.

The main agricultural activity is rice farming. Rotation crops are mostly cassava and soybean.

Because of the sandy soil and close proximity to the sea, coconut groves are abundant and the coconuts are rich in oil. Many farmers therefore produce coconut oil. This is a flourishing cottage industry and is done all the year round. Neither the dry season nor the wet season seem to influence the oil yield appreciably.

Market days constitute a five day week and markets are held in five different villages on a rotating base. Every day of the five day market week, the market is held in a different village. There are however some bigger market centres where location warrants the holding of a market every day.

The five days of the five market week are called: Legi, Pon, Kliwon, Pahing and Wage. Every calender in Indonesia therefore prints both the Gregorian seven day week and the Indonesian five day market week side by side.

For example the 16th of April which falls on a Monday coincides with Legi. Western observers might be mystified why both calenders are still preserved. One of the reasons is that every day of the five day week has its own connotations of bad luck and good for the market goers.

If you go on Legi market day things might turn out very sweet for you since Legi means sweet.

Why shouldn't everyone go to Legi market day? For many different reasons. Sometimes because Legi market is too far from your village. Or maybe because you were born on a day and hour that Legi day brings you bad luck. Also some markets specialise in one product, for example ducklings, and another in a different product, say cassava.

There are intricate astrological tables for bad and good days.

From the modern point of view the rotating of markets insures a fairly evenly distributed flow of income over the countryside.

In many places this system is breaking down, because of the continuous growth of markets at railway junctions. Many village markets close to the railway junctions are less and less frequented with a subsequent impoverishment of the surrounding countryside.

For the cottage coconut oil industry this of course is of far reaching consequences.

Close to the railway junction all coconuts are sold to buyers from the towns where oil is produced in big factories. Since the town buyers are desperate to keep a continuous flow of coconuts for the big factories, the price goes up. The cottage industry cannot compete and dies out.

Yet factory pressed oil is inferior in every respect-taste, colour and shelf life.

THE COTTAGE COCONUT OIL PRODUCTION

The following is a description of the oil production in Panjang Rejo, a typical village in Central Java.

The oil production from coconut was done in a room of 8×5 m^2. The walls were baked brick and the roof baked tiles.

In essence the process is a water extraction through the following steps :

1. The coconuts are cracked and the fruitwater collected.
2. Coconut meat is separated from the hard shell.
3. Coconut meat is soaked in water for twenty four hours.
4. Shredding of the coconut meat.
5. Shredded meat mixed with water and pressed out.
6. This gives a milky substance. The coconut milk is subsequently cooked over a (coconut shell) charcoal fire.
7. The coconut oil will separate and float on top.
8. Coconut oil is skimmed off and stored in old kerosene cans.

The coconuts are bought at sunrise on the open market. In this particular place the daily amount was 750 coconuts. Transportation of coconuts was by bicycle. One bicycle holding 250 to 350 coconuts.

It takes three people half an hour to crack open the shells and remove the meat of 500 coconuts, and two people to shred the seven hundred and fifty coconuts and this shredding goes on continuously for four hours.

While two people shred the coconuts one man is treading the coconut shreddings in a bambu basket, called a "tumbu", after they have been soaked in water.

The tumbu is a cylindrical basket woven of thick bambu plaits with a diameter of 50 cm and a height of 75 cm. After filling the tumbu to the rim with coconut gratings, pails of water from a nearby reservoir are thrown over the gratings till it becomes a soggy mass. This soggy mass is treaded and the coconut milk flows through the tumbu walls from between the bambu plaits into an earthenware pot. This pot can hold about seventy liters.

After the pot, which is called the "jedogan", is full the fire is lit, and after the oil has separated it is skimmed off with a ladle and collected in old kerosene cans which hold 20 liters each.

In a nine-hour working day four people can produce five kerosene containers of coconut oil, which is equivalent to a hundred liters. Size reduction is done on old bicycle frames which have been turned upside down on a bambu or wooden frame.

The back tire has been replaced by a steel band made of an old oil drum and roughened with a chisel so that one ends up with a circular band rasp.

The operators sit on saddles fixed on the wooden frame in such a position that while pedaling "back wards" they can hold a piece of coconut meat in their two hands against the turning band rasp. The gratings fall on a bambu mat on the floor and are periodically collected to fill the tumbu.

Stubs of coconut meat too small to hold, called "chikalan", are also collected and together with the pressed gratings sold for either human consumption or stock feed.

One wonders if size reduction could not done by specially designed machines which are on the market today and are able to grind the coconut meat to a flour-like consistency. Experience has shown that the particles of flour so produced are heated up internally in such a fashion that the oil extraction is greatly reduced. Furthermore this flour clogs up the moving parts of the mill causing a few days' delay dismantling the mill and putting it together again. A few cottage industries in the neighborhood using these mills had to close down because of these reasons.

The particles can also not be too big because the diffusion of water into the meat will not be sufficient.

The optimum size therefore is very important and it is for this reason that the making of the band rasp is left to specialists.

They work up the metal strips of oil drum steel with a chisel. The result is a set of raised teeth not unlike those on shark skin.

A great deal of expertise and skill is needed not to end up after a nine-hour working day with the skin of one's fingers removed.

Summary of equipment in the traditional process.

1. Two grating machines made from old bicycle frames.
2. One sturdy cylindrical bambu container of 60 cm diameter and 75 cm height.
3. One 100 liter earthenware cooking pot.
4. Four 100 liter earthenware water containers.
5. Two sheet iron pails.
6. A 10 meter length of rope to assist the bambu press pole in its leverage by capstan action.
7. Two bambu baskets to hold the coconut meat taken from the soaking reservoir.
8. One 220 liter oil drum for collecting the oil produced.

BY PRODUCTS

Coconuts are brought to market by individual owners of coconut groves already free from coconut fiber.

These fibers are sold separately and have a multitude of uses like the manufacture of ropes, doormats and carpets, to name only a few.

The price of the coconuts without the fibers is Rp. 60.00 apiece, and cottage coconut oil producers can handle up to two thousand a day. These are bought fresh everyday. Stock piling does happen if there is enough capital.

The coconut gratings are called "parutan" before they are pressed out, and "ampas" after the pressing out of the coconut milk.

After the foot treading has produced the maximum amount of coconut milk the tumbu is emptied on guni sacking.

The guni sacking is then neatly folded, forming a big pillow of pressed out gratings. This pillow is put between a wooden anvil and pressing pole on top of the pillow, and by jumping up and down at the end of the five meter pole the last drops of coconut milk are pressed out by lever action.

The "ampas" is sold for stock feed mostly to Chinese owners of piggeries.

Sediment which is left in the earthenware cauldron after skimming off the coconut oil is called "blondo", and mixed with palm-sugar is sold as a delicacy.

The coconut shell is burned to charcoal and is sold by the truckload. Coconut shell charcoal is a very high grade charcoal used especially in metal working shops and by village smiths, since it can reach quite high temperatures.

The coconut fruit water is either thrown away after collection or used as fertilizer.

We see therefore that not one part of the coconut is unused.

It is because of this that the use of solar energy for the replacement of fuel in the cottage coconut oil industry is not a simple problem of replacing coconut shell charcoal by solar energy. The whole problem has to be studied integrally.

ECONOMIC CONSIDERATIONS

A breakdown of daily earnings and expenditures are given in the following balance sheet.

Income		Expenditures	
1. coconut	US$ 76.00	1. coconut	US$ 80.00
2. Ampas	,, 1.20	2. labour which amounts to 36 man hours a day with breakfast and lunch provided	,, 6.96
3. Blondo	,, 10.00	3. coconut shell charcoal	,, 2.40
4. Cikalan (stubs)	,, 1.92	4. transport	,, 2.40
5. Coconut shell charcoal	,, 4.96	5. coconut meat stubs	,, 0.80
Total	US$ 94.08	Total	US$ 92.56

The daily net cash earnings are therefore $ 1.52 which means a monthly total of $ 45.60.

For a working year roughly 300 days this means a yearly income of $ 456.0

Replacing the traditional process by a process using solar energy would mean a daily saving of $ 2.4. Which means an amount more than the total daily earnings, adding a yearly income of about $ 720.00.

Since charcoal is a byproduct which fetches a high price the charcoal saved can be sold and add to the total income.

This of course is an added incentive for the acceptance of solar energy.

There are however other considerations.

The new process must be convenient, that is to say not cause too much fuss. It should be fairly labour intensive or at least not put people out of work.

SOLAR ENERGY CONSIDERATIONS

Yogyakarta and its immediate surroundings have an insolation of 15.60 MJ/m^2 per day on an inclined surface of 10°.

The choice of introducing solar energy in this particular village and with this particular producer has been arrived at as follows.

Experience has shown that solar energy has to be introduced into the village by easy-to-understand cost effective small steps.

The number of new end products must be kept to an absolute minimum and solar energy use should not replace too many things at a time.

Also the introduction of new technology in rural surroundings should not involve unknown end products.

Rather, a well known product like in our case coconut oil should still be the end-product.

Acceptance of solar energy technology therefore would entail mainly a replacement of a part of the chain of production, and slowly complete new technologies using solar energy can be introduced.

Another principle we adhered to was not to be too serious about the matter but to introduce the new technology as a kind of novelty, a kind of school demonstration which should be taken not too seriously.

This has many advantages. The ingrained suspicion of the villagers to everything new, especially if it will cost a large amount of capital, will be thereby lulled to sleep.

Another advantage is that even with a small demonstration plant many local conditions can be scouted out. For example the location of the well as a future supply of cooling water for distillation jackets will be the same for a 10 liter distillation unit as for a 100 liter unit.

The positioning of a small unit in shadow-free locations in a village tucked away beneath shadow-giving trees will be much easier than lugging around a big unit.

It was also fortunate that the eldest son of this particular producer worked in our laboratory as a technician. Performance data could be therefore gathered routinely without undully frigthening the villagers.

THE SOLAR POWERED SOLVENT EXTRACTION PROCESS OF SHREDDED COCONUT

The depletion of non-renewable energy sources and progressively worsening pollution and unwise use of forests makes it imperative to introduce the use of solar energy on a massive scale at the earliest possible stage, for Indonesia not less than for the rest of the world.

However, owing to the high initial capital investment, the introduction of solar energy devices for domestic use will be unattractive in the near future. Their use in producing industrial process water for small industries and for enterprises such as hotels, hospitals, and small food-processing plants, solar-energised solvent extraction processes of seeds, roots, and leaves, and industrial crop drying stand a much better chance, since the benefits are much more obvious, because of both savings and of adding to income or creating new sources of income.

Solar energised solvent extraction for cottage industries could be attractive especially in Indonesia, where there is an abundance of oil-containing seeds, where aromatic oils for the perfume industry are still extracted from flowers, and medicinal use of herbs is widespread and intensive.

The use of solar energy economises on traditional fuels and for solvent extraction, where large quantities of inflammable liquids are used, it may well be the only safe method.

It is with the above in mind that laboratory-scale experiments were conducted in which crushed cotton seed and shredded coconut were solvent-extracted in a Soxhlet-type extractor; the heat needed being provided by solar energy.

EXPERIMENTAL PROCEDURES

The system as outlined in Fig. 1 consists of a solar energy collector and the extraction system, which contains a condenser, an extraction vessel, and an evaporator.

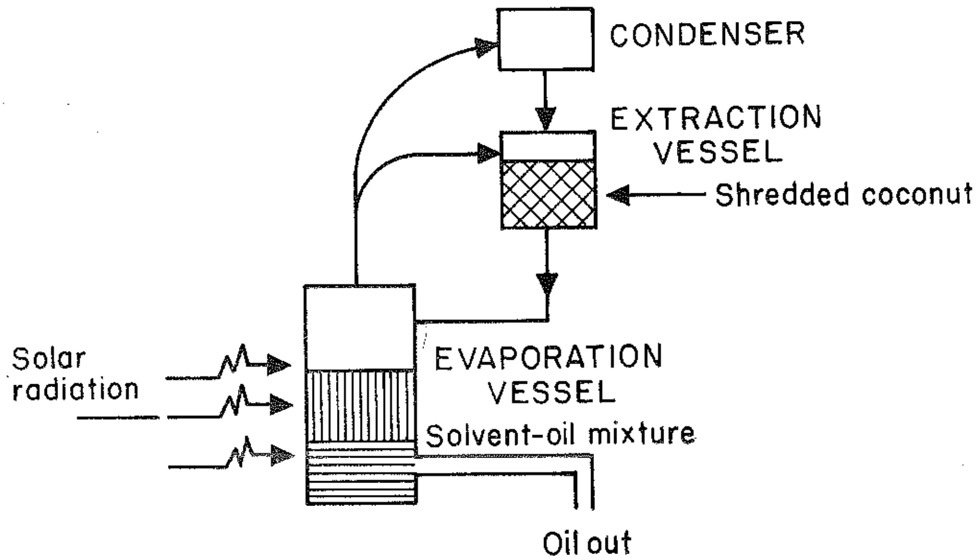

Fig. 1 Experimental system for shredded coconut.

The extraction vessel was filled with shredded dried coconut. Ethanol was evaporated in the evaporation vessel placed in the focus of the solar energy collector, in this case a ring paraboloid mirror with an aperture of 1 m. Solvent vapour condensed in the water-cooled condensers (flow rate 1.5 l/min), and solvent liquid circulated back to the evaporator by way of the extraction vessel, extracting oil from the shredded coconut on its passage to the evaporator. In this way a progressively oil-enriched mixture accumulated in the evaporator. Oil separated out in the evaporator after standing over-night and was bled off in the morning.

Results

Extraction of shredded coconut

The amount of oil produced over a period as a percentage of the total available per 100 g of dry matter is given in Fig. 2. After 4 hr the curve levels off, indicating that the maximum amount of oil has been extracted.

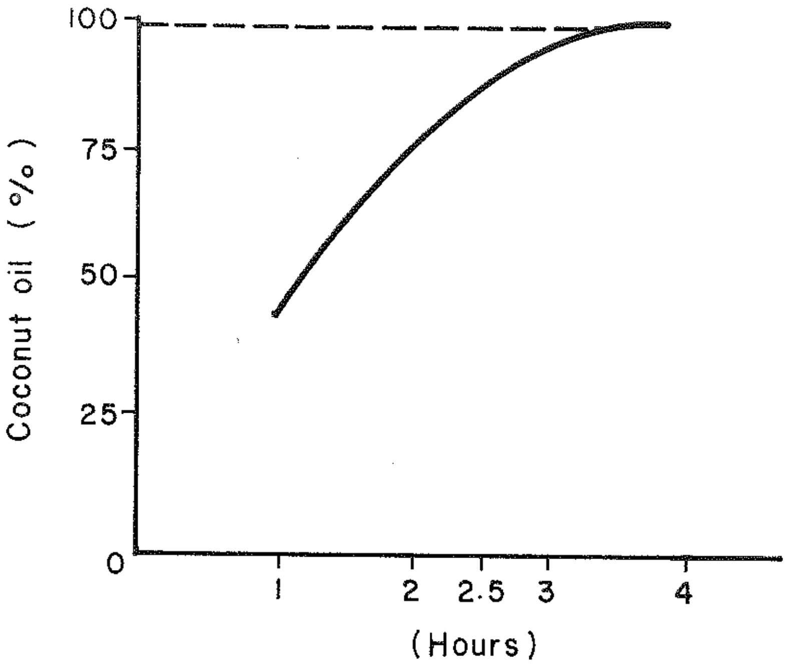

Fig. 2 Experimental yield of coconut oil.

[*Editorial Note.*

The author has supplied two extra diagrams which are reproduced in Figs. 3 and 4.]

Discussion.

From the above results, from laboratory tests in which the parameters were far from optimum, it can be seen that solar solvent extraction is a definite possibility. It should be remembered that the solar energy part of the system has been interphased with the rest of the system in the most elementary, that is in a rather inefficient, way. In the actual cottage-industry application, the solar energy collector will form a built-in part of the total system. For Indonesia the most economic system will be a stationary flat-plate collector where convection currents in the space between absorber plate and glass cover are suppressed.

The level of technical knowhow in the typical Indonesian village is high enough to cope with problems of construction and maintenance. However, a standard operational procedure

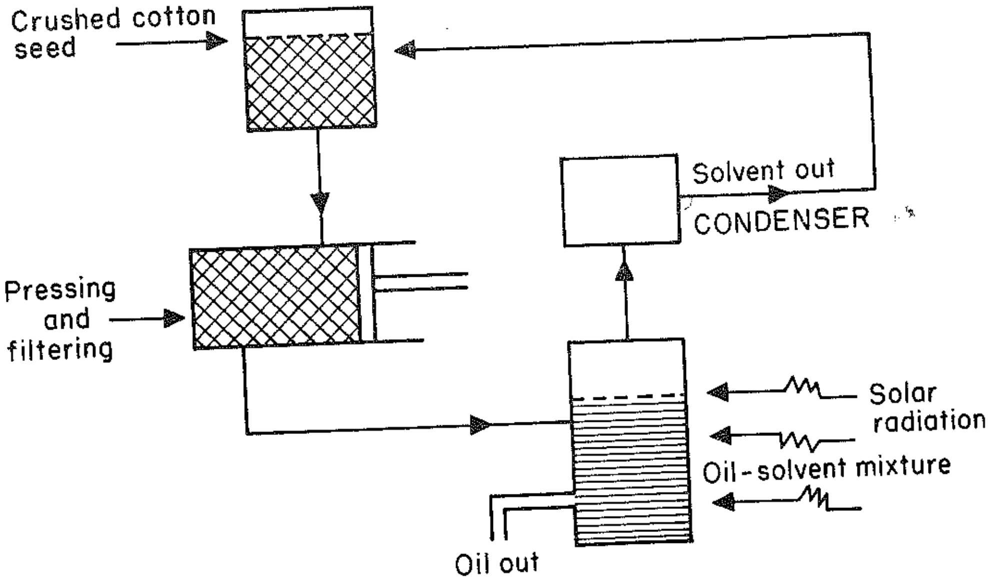

Fig. 3 Experimental system for crushed cotton seed.

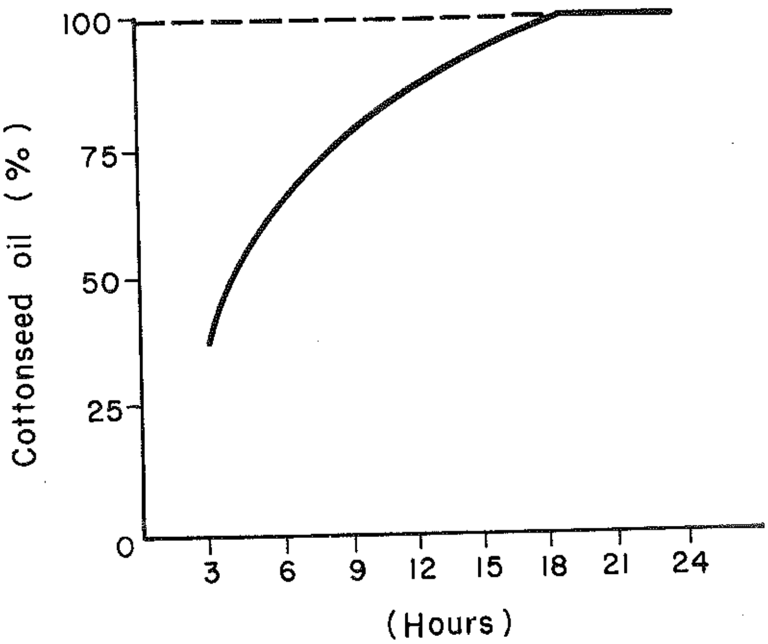

Fig. 4 Experimental yield of cotton seed oil.

for the extraction process proper as well as for storing and handling large quantities of inflammable liquids has to be taught.

Future work will consist in scaling the laboratory experiments up to pilot-plant proportions.

Loss of solvent is the most serious objection for solvent extraction. However by using hexane as the solvent, the price of the solvent goes down drastically. Also hexane can be manufactured in the village by solar energy powered distillation of premium gasoline.

The oil yield on a laboratory scale is about twice that of the water extraction process. It remains to be seen if scaled up to cottage industry level, solvent loss can be made smaller and oil yield can be made higher.

The development of the village unit will be carried out with the help and the advice of the villagers themselves.

It is believed that an "organic" growth like this will help to overcome the reluctance of accepting a new technology, be it solar or any other new technology.

Once the basic principles of solvent extraction and distillation are driven home it will be up to the villagers to use this process. Solar energy will come in only sideways, that is to say only if by using solar energy added earnings are made, not by mere propaganda.

ACKNOWLEDGEMENTS

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CALL FOR PAPERS

Symposium on Solar Science and Technology organized by the Regional Centre for Technology Transfer (RCTT), an institution established by the United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP) will be held at the United Nations Building, ESCAP Headquarters and at the Asian Institute of Technology in Bangkok, Thailand from Tuesday 25 November to Thursday 4 December 1980.

It will be sponsored by the International Solar Energy Society (ISES), United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Conference on Trade and Development (UNCTAD), United Nations Environment Programme (UNEP), Food and Agriculture Organization of the United Nations (FAO), United Nations Industrial Development Organization (UNIDO), World Intellectual Property Organization (WIPO) and the Asian Institute of Technology (AIT).

The objectives of this Symposium are:

1. To expose latest developments in solar energy research and to determine guidelines for research suitable for institutions of higher learning in the ESCAP region,
2. To determine technologies available for immediate transfer in the manufacturing and marketing of solar energy equipment by entrepreneurs in the ESCAP region.

Scientific and technical papers concerning thermal conversion and photovoltaic conversion of solar energy for application in developing countries especially those in the ESCAP region are called for.

Authors should submit extended abstracts to be reviewed for acceptance. Abstracts should be two pages long, clearly typed on $8\frac{1}{2}''$ and $11''$ paper with margins $1''$ wide all round ready for photocopying. They should contain: title, author's name and affiliation, text (including tables and figures if necessary), and key references all contained on the two pages allowed. Accepted abstracts will be reproduced and circulated to participants in advance of the Symposium. Three copies of each abstract must reach ESCAP by 15 September 1980. The full-length papers, which will be due on the first day of the Symposium, will be published in the proceedings of the Symposium.

The Symposium will be open to all scientists and technologists interested in the development of solar energy, and there will be no registration fee charged to those participants from governments and non-profit organizations.

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