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Use of Geothermal Energy for Drying and Cooling Purposes

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ABSTRACT

Indonesia has the world's largest potential of geothermal resources. However, only a small portion of these resources have been utilized to supply Indonesia's growing energy needs. Some of geothermal power generation facilities can provide excess heat for the main power generation system but some have untapped steam from small wells. The purpose of this paper is to explore the possibility to utilize dry steam or hot water from the geothermal power plant for drying and cooling of locally produce crops and, which could help to increase value of the surrounding farms. Steam or hot water available from geothermal power plant will be combined with active and passive solar utilization methods.

In the drying applications, geothermal energy may be used to dry several crops available in the area such as coffee berries, tea, rough rice or even fish from the nearby lake. In the cooling system, the possibility to combine the already tested nocturnal cooling system and steam powered absorption or adsorption cooling will be discussed and their economic benefit of both the drying and cooling system will also be presented**.**

1. INTRODUCTION

Indonesia has the world's largest potential of geothermal resources. However, only a small portion, about 1100 MWe of these resources, have been utilized to supply Indonesia's growing energy needs. Some of geothermal power generation facilities provide excess heat for the main power generation system but some have untapped steam from small wells. Geothermal resources are available along mountain ranges from Sumatera, Java, Sulawesi, Bali and West and East Nusa Tenggara. Hot water or dry steam at low pressure is available from the main power plant that may not adequate to generate electricity. In such cases the energy can be used to dry crops that are available in the surrounding area such as coffee berries, tea, rough rice or even fish caught from nearby lake. The available heat is also adequate to power a LiBr absorption chiller or Silica gel–MeOH adsorption cooling machine to cool vegetables such onions, potatoes, chilis and other vegetables grown nearby the plant. Direct applications of geothermal energy have been extensively conducted by BPPT (Taufan, 2009). For example in Lampung well geothermal heat was for cocoa and copra processing, in Kamojang for mushroom growing, for palm sugar processing in Lahendong, Sulawesi and in Wayang Windu for tea processing. Fig.1. shows a method of tapping geothermal heat for thermal processing (Taufan, 2009).

The purpose of this paper is to explore the possibility to utilize dry steam or hot water from the geothermal power plant for drying and cooling of locally produce crops and therefore, which could help to increase value to activities in surrounding farms.

2. DRYING APPLICATIONS

Drying is the process of taking moisture out of a substance by applying heat to the substance. Beside temperature, level of relative humidity (RH) and air flow rate are important parameters in any drying process, and therefore, if the RH is low, low temperature is adequate to accomplish the drying process. The process can be accelerated by replacing the saturated air with another low RH air. This condition can be created by increasing the air flow rate. Drying temperature requirement of several crops can reach near 90^{o}C, but usually a moderate temperature level 50 to 60^{o}C with RH level of around 40% may be adequate to conduct a drying process. Low pressure steam from power plants that is not adequate to generate electricity, can be directed to pass through heat exchangers that belong to drying facilities. Coffee berries, for example under 50 to 60^{o}C can be dried from 178% db down to 14%wb for about 60 to 70 hours. Rough rice on the other hand requires lower temperature of less than 45^{o}C and can be dried from the initial of 25%wb to 14%wb within one or two days. Sliced fish can be dried from 74%wb to 33% wet basis in 17 hrs using drying temperature of 40^{o}C.

2.1 Drying System Optimization

In order to reduce the initial cost system optimization of the conventional collector-drying system was conducted in early 1990s by the author (Kamaruddin, 1992, 1994). The conventional system usually consists of a flat plate solar collector, a blower and a drying chamber containing rectangular drying bin. The imposed constraints of the objective function were that the system should be capable of operating at a specified drying temperature and air flow rate. The volume of the perforated floor drying bin should be able to hold the specified drying load at a specified depth. After applying the Lagrange multiplier optimization process, it was found that the highest cost was for the solar collector, followed by the drying bin and the lowest cost was for the blower. From this optimization study then it was decided to create a novel solar drying system where solar heat collector should be integrated with the drying chamber to reduce the construction cost significantly. Such solar dryer can be called an Integrated Solar Collector-Drying Chamber (ICDC) and to ensure continuous operation of the system an auxiliary heating unit could be added. Furthermore, an innovative wind mill such as the PDID (Pressure Difference Induced Draft (Ngoc and Srivastava, 1992)), Savonius type wind mill or a simple vortex may also be added to form a hybrid ICDC solar dryer.

From the above findings several prototypes of hybrid ICDC solar dryer have been developed and some have been installed in several Indonesian villages (Kamaruddin, 2007). Table 1 shows performance test results of the dryer when applied to various tropical crops in Indonesia. Figure 1 shows one type of the hybrid ICDC solar dryer with drying trolleys inside the transparent structure, equipped with PDID, Savonius wind mill and a biomass stove to supply heat by means of a heat exchanger unit.

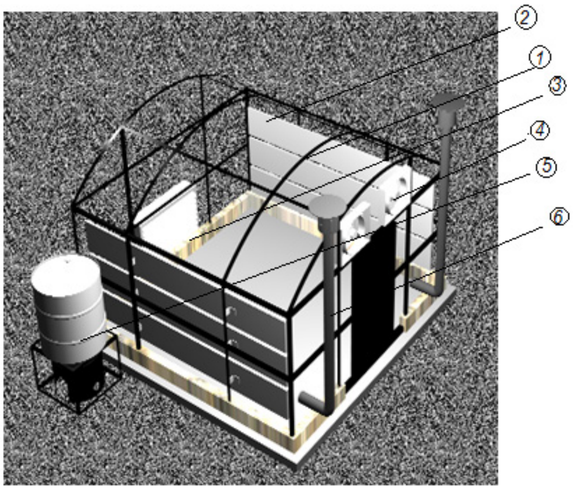

Figure 1: A typical hybrid ICDC solar dryer showing 1, angle frame where transparent materials such as polycarbonate can be fixed, 2, Heat absorber plate, 3, heat exchanger, 4 electric fan, 5, Hot water tank, and 6, PDIDs.

2.2 Heat Conversion Method from a Geothermal Power Plant

Some of the power plants can provide their low pressure steam or hot water adequate in producing heat both for drying of various farm crops and fish at temperature <100°C. Such temperature level will be adequate to accomplish drying operations for various tropical crops and fish as shown in Table 1, where the required temperature is between 37 to 51°C. Figure 2 shows a method to tap heat from a geothermal power plant (Taufan, 2009). Such heating system can replace the function of the biomass stove in a hybrid solar dryer as described in the previous section. Some geothermal power plants in Indonesia such as those in Kamojang, Wayang Windu or in Lahendong already have their respective project related to direct use of available steam and hot water for agricultural purposes such as for drying and plant growing.

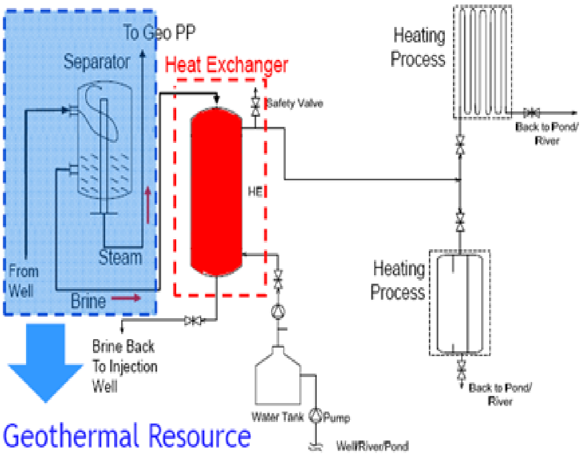

Figure 2: A heating system using geothermal energy sources (Taufan, 2009).

Table 1: Drying temperature and drying time of several Indonesian crops (Kamaruddin, 2000).

Commodity	Drying Temp. (°C)	Drying time (h)	Load (kg)
1) Cocoa			
a. Lab test 1	50	40	228
b. Lab test 2	49.2	32	400
c. Field test	45.8	43	190
2).Robusta coffee	37	60	1114
3). Vanilla pods	51	52	52
4). Seeds			
a. chilli	40	4	1.6
b. cucumber	40	9.5	5.4
5). Fruits			
a. Papaya	39	33	40
b. Banana	40.6	11	18
6). Woods			
a. Bayur	39.3	158	728
b. Kemiri	48.5	96	780

2.3 The Economic Benefit of Steam Operated Hybrid ICDC Solar Dryer

A case study was conducted taking example of a cooperative in Cimahi City, West Java, using a venturi type hybrid ICDC solar dryer to dry jerked banana spike. The cooperative produced around 35,000 packs a year for a 200 working days. The study has shown that the price of the product should be sold >Rp 3800/pack (US$0.38) (the current selling price was Rp.4000/pack) in order to make the investment worth undertaken. This conclusion was based on the assumption that in the 1st year the drier was given to the beneficiary (manager of the cooperative) as grant and let him borrow money from the bank at the commercial rate of 17.5% as working capital. It was also assumed that after 5 years operating the manager would capable to buy the drier himself at a cost of Rp. 80 million (US$ 8000) without any necessity to borrow money from the bank. Since the ICDC solar dryer is also heated by a heat exchanger, integrating the heat withdrawal system as shown in Fig.2 with the ICDC solar dryer may results in similar value of IRR, provided that system could produce air temperature of 50°C.

3. COOLING APPLICATIONS

Most of tropical fruits and vegetables required storage temperature higher than those grown in cool climate. As shown in Table 2, the preferred storage temperature is between 13 to 15°C. Lower storage temperature as recommended above may result in chilling injuries and other negative effect on the quality of the stored commodity. Banana, for example, will soon create black spot if stored, say, at 0°C.

Several cooling methods such as the absorption or adsorption cooling can be operated by applying heat to the system to produce refrigeration effect. The level of temperature required for the two types of heat operated cooling machine is usually less than 100°C. Hence low pressure steam or hot water from geothermal power plant which can produce between 70-100°C then can be used as source of heat supply for temporary storage crops grown in the vicinity of a power plant. Although some geothermal power plants in Indonesia already have their respective project related to direct use of available steam and hot water for agricultural purposes none has their activity to involve in utilizing steam or hot water for cooling purposes.

Table 2: Fruits and vegetables, 13 to 15°C (55 to 60°F), 85-90% relative humidity. Many of these products produce ethylene. These products also are sensitive to chilling injury. (The Ohio State University, 2009).

Atemoya	Ginger root,	Papayas
Avocados	Granadilla	Passion fruit
Babaco	Grapefruit	Pineapple
Bananas	Guava	Plantain
Bitter melon	Jaboticaba	Potatoes, new
Black sapote	Jackfruit	Pumpkin
Boniato	Langsat	Rambutan
Breadfruit	Lemons*	Santol
Canistel	Limes*	Soursop
Carambola	Marney	Sugar apple
Cherimoya	Mangoes	Squash, winter (hard shell)
Coconuts	Mangosteen	Tomatillos
Feijoa	Melons **)	Tomatoes, ripe
*citrus treated with biphenyl may give odors to other products **) Except cantaloupes		

3.1 Cooling System

As mentioned in the previous section, there are basically two types of cooling method using heat to produce cooling effect. Table 3 shows one example of such system in which LiBr-H_2O solutions was used as the absorbent-refrigerant. This experimental absorption cooling machine used a bubble pumping system to circulate the working fluid of LiBr-H_2O solutions (Kamaruddin, 1976). As shown in the Table 3, with operating temperature between 69-76^oC, the system was capable to produce evaporator temperature of between 2-6^oC which is seems adequate to operate a cool storage using available heat from a geothermal power plant.

Table 3: Test performances of an experimental bubble pump absorption cooling machine (Kamaruddin, 1976).

Parameter/Exp. run	4	5	6
A. Operating Temperature & Li BR concentrations			
Tg (C)	71	69	76
Te (C)	5.9	2.3	3
Tc (C)	25	22	27
XI (%LiBr)	52.9	50.7	52
XO(%LiBr)	54.5	51.9	54
B. Heat transfer	U (W/m^2 C)	(kg/m^2 s)	q (W/m^2)
Generator	639	625	9472
Condenser	866	1787	1787
Absorber	866	279	3034
Evaporator	663	53	664

Table 4: Specification of the Yazaki LiBr-H2O chiller (The Solar-AC FAQ, 2009).

Model	SC10
Cooling effect	Capacity: 120,000 BTU/hr (35 kW thermal)
	Chilled temperature: 44.6^{o}F (7^{o}C) at outlet, 54.5^{o}F (15.5^{o}C) at inlet.
Heating	Capacity:166,3000 BTU/hr(48.7 kW thermal)
	Hot water temperature: 131^{o}F (55^{o}C) at out let, 117.3^{o}F (47.4^{o}C) at Inlet.
Chilled/Hot water flow rate	24.2 gpm (91.6 liters/min)
Cooling water	Heat rejection: 291,400 BTU/hr (85.4 kW)
	Inlet water temperature: 87.8^{o}F (47.3^{o}C)
	Rated water flow: 80.8 gpm (305.8 liters/min.)
Heat Medium	Input: 171,400 BTU/hr (50.2 kW thermal)
	Inlet Temperature: 190.4^{o}F (88^{o}C) Range: 158^{o}F (70^{o}C) [min] − 203^{o}F (95^{o}C) [max].
	Rated Water flow: 38 gpm (143.8 liters/min.)
Electrical power supply	210 W (208 V, 60 Hz, 3 ph)
Piping	Chilled/hot water: 1-1/2 in. NPT
	Cooling water: 2 in.NPT

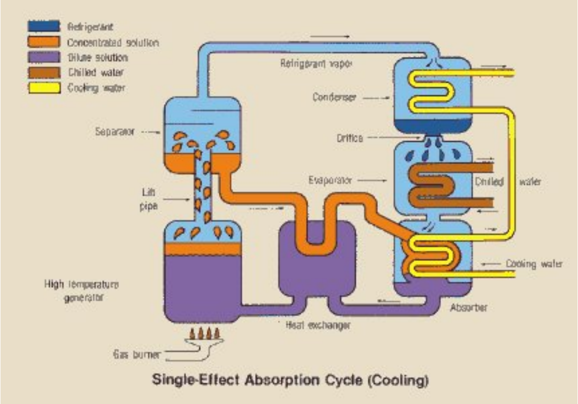

Figure 3: The Yazaki Chiller (The Solar-AC FAQ, 2009).

Figure 3 shows a commercially available LiBr-H_2O absorption chiller. As indicated in Table 4, the chiller is capable to produce low temperature adequate in substituting the auxiliary cooling unit of the previously described hybrid nocturnal cooling system. The temperature level available from the geothermal power plant is also suitable as for the generator of the chiller.

3.2 Cool Storage System Optimization

Nocturnal cooling can be applied under the Indonesian climatic conditions. Such possibility was tested in a study by Trisasiwi (2000) and then continued by Gunadnya (2009). Better performance was shown for system installed in highland area, such as in Candikuning village in Bali (±

1200 m asl) where geothermal resources are mostly available. Gunadnya (2009) for example, had conducted an optimization process of the existing temporary cool storage powered by a hybrid nocturnal cooling system to improve its performance. The tested cool storage system as shown in Figure 4 has a floor having a dimension of 3 m x 4 m with height of 2.5 m. The roof was designed in such a way to form a shallow pond with 4 m x 5 m in dimension and has 0.1 m depth. The storage was also equipped with 450 liters of chilled water tank, a recirculation water pump, one 1 kW compression type auxiliary cooling machine, and one 746 W centrifugal blower placed in front of a air duct where pre-cooler, and evaporator were placed to blow conditioned air (low temperature, high humidity) into the storage room. This auxiliary cooling machine can be substituted with either absorption or adsorption cooling with the same cooling capacity.

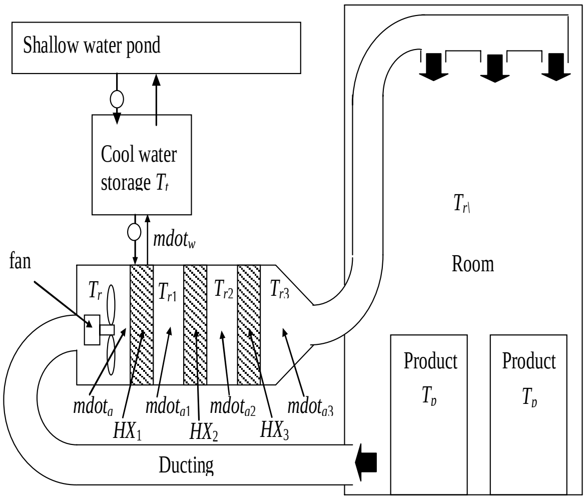

Figure 4: Improved design of a hybrid nocturnal cooling system (Gunadnya, 2009).

Optimization results have provided several cooling scenarios with different value of total initial investment cost both for the building and its major component.

For the case of storage temperature of 5°C, surface area of cooling water pond, and load of 5 tons of vegetables the total cost including building was: Rp.94,120,689.

The respective component cost were as follows

1) Cost for heat exchangers (pre-cooler and cooler) Rp.2,10,000

2) Chilled water tank, Rp.30,000

3) Auxiliary cooling machine, Rp.90,880,000

4) Recirculation pumps, Rp.230,000

5) Fans Rp.787,000

3.3 The Economic Benefit

The vegetable farms at Candikuning village is owned by the local government but is being managed by a cooperative. Gunadnya (2009) had explored the possible benefit of the installed temporary cooled storage facility as described in the previous section. For this purposes he selected 8 scenarios for comparison, namely, scenario 1: As the base case, where the cooperative sells the vegetables without using the cool storage facility; the unit responsibility is to take care of the overhead cost of the farm while the maintenance cost is to be born by the owner (local government). Scenario 2: Same as for scenario 1 but also the cooperative will bear the maintenance cost. Scenario 3: The same condition as for the case 1 but the cooperative now utilizes the cool storage facilities, without operating the nocturnal cooling unit. Scenario 4: The same as condition for scenario 2 with the inclusion of the condition stated in scenario 3. Scenario 5: Same as scenario 3, but with the cooperative includes the operation of the nocturnal cooling unit. Scenario 6: Same as scenario 4 with the inclusion of condition stated in scenario 5. Scenario 7: Same as for the case of scenario 3 with the cooperative now uses the pre-cooling facilities. Scenario 8: Same as in scenario 4 with the cooperative using the pre-cooling facilities. Although scenario 1 seems to be preferable from the economic indicators, however, by doing nothing, there is a danger that the storade vegetables under natural condition may not compatible with the specification of the buyer.

Table 5: Comparison among different economic scenarios.

Scenario	NPV(xRp.10^7)	IRR	BCR	PbP
#1	19.96	71.77	1.08	1.38
#2	7.31	35.22	1.03	2.67
#3	25.05	85.15	1.11	1.17
#4	7.74	36.45	1.03	2.59
#5	26.08	87.83	1.11	1.13
#6	8.26	37.93	1.03	2.50
#7	26.66	89.35	1.12	1.12
#8	8.84	39.58	1.04	2.41

Note:currency:1 US$=Rp.10000

CONCLUSIONS

1) Available geothermal heats from existing geothermal power plant Indonesia, can be used for drying and cooling of tropical fruits and vegetables grown in the vicinity of the power plant

2) Several design configurations of solar assisted dryers and cooling units developed by the author can be integrated with available heats generated from geothermal power plants.

3) Direct uses of geothermal heats, both for drying and cooling, may provide economic gains for local farmers provided that working capital can be made accessible.

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