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Utilization of Geothermal Energy In Poultry Farming

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Abstract

The high demands of energy, especially traditional sources of energy, prompt the use of other sources. The renewable sources of energy are seen as the possible alternative, where most projects in Jordan were focusing on the solar energy and wind energy use. Less attention was driven to geothermal energy use, hence, in this paper a standard closed poultry house with (40 m length /12 m width /2.5 m height) is selected; to study its heating loads required for chicken fattening. This load is then supplied using geothermal energy in Amman airport area. The results show that supplied energy is more than enough to meet the needs of the poultry house. Finally, after proper selection of the system components, a feasibility study for the geothermal system use in this field is performed, showing promising possible cost reductions in it.

Keywords: Renewable Energy, Geothermal Energy , Poultry Farming and Thermal calculation

Nomenclature

A	Area (m^2).
Cp	Air specific heat (kJ/kg.K).
E	Monthly energy saving (kJ).
$\dot{m}_{Geo}$	Ground water mass flow rate (kg/s).
Q	Heat loss (kW).
T_{Geo}	Ground water temperature (^oC).
T_i	Inside temperature (^oC).
T_o	Minimum outside temperature (^oC).
U	Overall heat transfer coefficient (W/m^2. K).
$\dot{V}$	The ventilation required for the birds (m^3/s).
ρ	Air density (kg/m^3).

1.Introduction

The increasing consumption of fossil energy sources, beside the lack of local sources of it; urges to look for alternative sources for it. The alternative sources of energy have to be in abundance to fill the gap resulting from the replacement of fossil fuels. Also many of these alternatives helps to reduce the pollution resulting from the fossil fuel use and these sources are called renewable energy sources.

The first renewable source to come into mind is solar energy, which can be used directly for heating purposes or can be converted to electricity through photovoltaic cells. Although Jordan is known of its abundance of solar irradiation in most of its locations, the problem of using solar energy is the need to lay solar equipments on large areas to harvest it. The second source of renewable energy used in Jordan is wind energy, in which large wind turbines are used to generate electricity. The problem of wind energy in Jordan is rarity of suitable sites for wind energy utilization and the high costs associated with the large wind turbines needed to supply enough amounts for different applications.

The third renewable energy source that has been used worldwide but is generally ignored in Jordan is geothermal energy. Still there were some significant efforts to investigate the presence of geothermal energy sites as in [1]. Others investigated the possibility of using this energy in the future comparing it to other forms of energy as found in [2]. The main uses of geothermal energy are in heating purposes, especially in Jordan due to the relatively low ground water temperature. Despite that some researchers looked for potential generation of electricity using binary power plants as in [3]. Others tried the opposite by utilizing the geothermal energy in cooling purposes as in [4]. A study of the use of geothermal energy in agriculture is seen in [5] which show different systems used for heating by geothermal energy. In [6] a more specific study on the heating process for fattening purposes is done with experimental results allover a whole year.

2. Heat Load Calculations

The objective here is to find if the geothermal energy will be enough to supply a standard poultry house with its need of heat. To do this the thermal loads of this house has to be calculated, then the supply loads from the geothermal site has to be calculated to see if they are sufficient for the house loads. Finally a fiscal study for the use of thermal energy is done to verify if this use is justified or not. To do all these calculations some data has to be gathered about the location of the house and the inside conditions of the house beside the specification of the house itself.

Location data (Queen Alia airport):

- Water temperature (T_{Geo}) =30 - 40 ^{o}C. [1]
- Water mass flow rate $(m^{\cdot}_{Geo})$ = 30 - 100 m^3 /hr. [1]
- Minimum outside temperature (T_O) =3 ^{o}C. [9]
- Ground temperature =10.4 ^{o}C.[10]
- Wind speed =3.3 m/s.[10]

Inside conditions of the poultry farm:

- The best range of inside temperature for adult chicken and is found in [5] to be (18-24) ^{o}C for adult birds.

Standard Poultry House specifications [5]:

- The design of the poultry house was taken from [8] as shown in figure (1) but with the reference [7] specifications.
- Length =40 m.
- Width = 12 m.
- Height =2.5 m.
- It has an air ventilation area around 6% of the house ground area.
- It has two (2 m x 2.5 m) steel doors.

Figure 1: Forced air furnace used for heating poultry house [11].

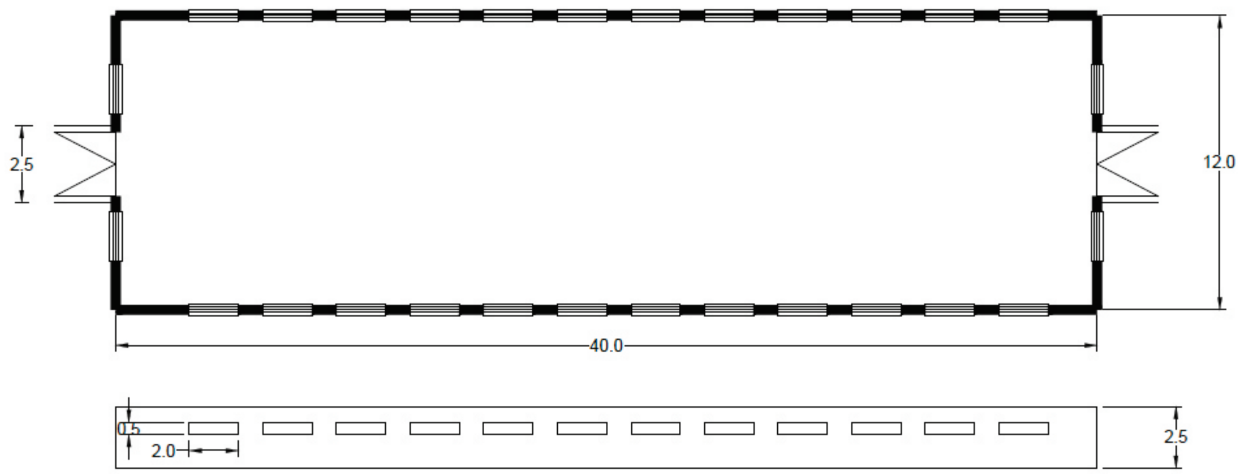

Figure 1:Graphical representation of a standard poultry house.

Calculations of the heating load for various components at the minimum outside temperature are shown below depending on the previous data.

Walls

All heat calculations use the same formula with (Q) as heat loss, (U) as overall heat transfer coefficient, (A) area through which the heat flows and finally (T) as temperature whether inside or outside the house.

$$Q_w = U_w\, A_w(T_i - T_o) \qquad (1)$$

Where

$$A_w = A_{total} - A_{doors} - A_{vents} \qquad (2)$$

$$A_w = (40 + 12)(2)(2.5) - 2\,(2 \times 2.5) - 0.06\ \times 40 \times 12$$

$$A_w = 218.8\, m^2$$

And

$$U_w = \frac{1}{R_o + \frac{x}{k} + R_i} \qquad (3)$$

$$U_w = \frac{1}{0.06 + \frac{0.05}{0.03} + 0.12} = 0.542 \frac{W}{m^2.K}$$

Here (x) is the thickness of the wall and (k) is its conductivity coefficient. (Ro and Ri) are outside air thermal resistance and inside air resistance respectively.

Then

$$Q_w = 2.253\, kW$$

Doors

$Q_{doors} = U_{door}\,A_{doors}(T_i - T_o)$ (4)

$A_{doors} = 2\,(2 \times 2.5) = 10\ m^2$

$U_{door} = 2.7\,\frac{W}{m^2.K}; Table\ 5.5\ \ in\ [10](steel\ with\ polysterene).$

$Q_{doors} = 0.513\ \ kW$

Ceiling

$Q_{ceiling} = U_{ceiling}\,A_{ceiling}(T_i - T_o)$ (5)

Where

$A_{ceiling} = 40 \times 12 = 480\ m^2$

And

$$U_{ceiling} = \frac{1}{R_o + \frac{x}{k} + R_i} \qquad (6)$$

$$= \frac{1}{0.1 + \frac{0.05}{0.03} + 0.04} = 0.553\,\frac{W}{m^2.K}$$

Then

$Q_{ceiling} = 5.04\ kW$

Ground

$Q_{ground} = U_{ground}\,A_{ground}(T_i - T_o)$ (7)

Where

$A_{ceiling} = 40 \times 12 = 480\ m^2$

And

$U_{ground} \approx 0.136\,\frac{W}{m^2.K}\ ; Table\ 5.8\ in\ [10]\ (width\ 12\ m\ , less\ than\ 1m\ depth\,)$

$Q_{ground} = 1.24\ kW$

Ventilation

$Q_{vent} = m^{\cdot}\ C_p\,(T_i - T_o)$ (8)

$m^{\cdot} = V^{\cdot}\rho$ (9)

The ventilation required$(V^{\cdot})$ for the birds is found using this equation:

$$\dot{V} = no\ of\ birds\ \times average\ weight \times flow\ rate\ per\ kg \qquad (10)$$

To find the flow rate per kg of chicken meat data form table 9-1in reference [7] are used at a presumed operating temperature (22 °C). The result is found using interpolation to be (0.851 cfm/ Ib of body weight) which equals (0.885 x 10^{-4} $m^3/s/kg$).

Assuming a bird density of (9 birds /m^2), the total number of birds will be:

$$no\ of\ birds = 9 \times 480 = 4320\ bird$$

The final assumption is that the average mass of these birds is (2 kg), so considering this information:

$$\dot{V} = 4320 \times 2 \times 0.885\ \times 10^{-4} = 7.643\ \frac{\mathrm{m}^3}{\mathrm{s}}$$

At (3 °C) the density of air and its specific heat are $\rho = 1.29 \frac{kg}{\mathrm{m}^3}$; $and\ \ C_p\ = 1.005\ \frac{kJ}{kg.K}$. This means that:

$$Q_{vent} = 188.3\ kW$$

Table 1: Heat loads for various components in the poultry house

Source of heat	Heat loss (kW)
Walls	2.2532024
Doors	0.513
Ceiling	5.04336
Ventilation	188.26658
Ground	1.24032
Total	197.316462

3.Geothermal energy supplies

In the previous section the maximum load throughout the year is found to be around 197 kW. To afford this amount of heat the water drawn from wells is used to heat the poultry house instead of using boilers. To calculate this amount of heat that can be supplied to the house we use the following equation:

$$Q_{Geo} = \dot{m}_{Geo} \times Cp_{water} \times (T_{Geo} - T_i) \qquad (11)$$

Taking the minimum values associated with geothermal water in the specified location.

$$\dot{m}_{Geo} = 1000 \times 30 \frac{m^3}{hr} = 8.33\ kg/s$$

$$T_{Geo} = 30\ °C$$

Then

$$Q_{Geo} = 8.33\ \times 4.186\ \times (30 - 22)$$

$$Q_{Geo} = 278.96\ kW$$

It can be easily seen here that geothermal energy is more than enough to supply the poultry house with its needs of heat.

4.Feasibility

In this section the profits of using geothermal energy in heating systems is studied. There are many heating methods in poultry houses that use different types of energy to create a suitable atmosphere for the chickens. Two of these methods depend traditionally on hot water coming from boilers. Here the boilers are to be replaced by underground water as a source of hot water. Then a rough feasibility study of this action is performed to assess the benefits of this use.

Fuel consumption:

There are two main fuels used in boilers for heating in general which are LPG and Diesel. To find the amount saved by the geothermal energy which happens to suffice all the needs of the poultry house, a detailed calculation on monthly basis is done. The previous calculations represent the heating loads during the coldest outside temperature in January. The same calculations are done and shown in table 2 below, but with the difference that the outside temperature is taken as the average. Also for the summer months from May to September the minimum average temperature is considered to avoid day time which does not need heating.

Table 2: Heat Loss of all components throughout the year.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Source of heat	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)	Heat loss (kW)
Walls	1.660	1.423	1.067	0.474	0.415	0.296	0.237	0.178	0.296	0.119	0.830	1.423
Doors	0.378	0.324	0.243	0.108	0.095	0.068	0.054	0.041	0.068	0.027	0.189	0.324
Ceiling	3.716	3.185	2.389	1.062	0.929	0.664	0.531	0.398	0.664	0.265	1.858	3.185
Ventilation	138.72	118.91	89.18	39.64	34.68	24.77	19.82	14.86	24.77	9.91	69.36	118.91
Ground	0.914	0.783	0.588	0.261	0.228	0.163	0.131	0.098	0.163	0.065	0.457	0.783
Total	145.39	124.62	93.47	41.54	36.35	25.96	20.77	15.58	25.96	10.39	72.70	124.62

To calculate the energy saved for a certain month the following equation has to be used:

$$E = no\ of\ days\ per\ month \times no\ of\ hours\ per\ day \times Total\ heating\ load \times 3600 \qquad (12)$$

For January the result will be:

$$E = 31 \times 24 \times 145.39 \times 3600 = 108170.9\ kJ$$

The energy saved for all months of the year is presented in table 3 below, beside the amount of fuel saved as a result:

Table 3 : Monthly energy and fuel consumption for Diesel and LPG boilers.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
E(kJ)x 10^8	3.894	3.338	2.503	1.113	0.9735	0.6954	0.5563	0.4172	0.6954	0.2782	1.947	3.338
LPG (kg)	10458.0	8964.0	6723.0	2988.0	2614.5	1867.5	1494.0	1120.5	1867.5	747.0	5229.0	8964.0
Diesel (kg)	9773.0	8376.9	6282.7	2792.3	2443.3	1745.2	1396.1	1047.1	1745.2	698.1	4886.5	8376.9

Now the savings calculations for each fuel type are done based on the following equations which are found for January as an example:

$$cost\ of\ diesel = m_{Diesel} \times Diesel\frac{price}{Diesel}density \qquad (13)$$

$$cost\ of\ diesel = 9773\ \times 0.66 \times \frac{1}{0.845} = 8168.41\ JD$$

For LPG savings calculations we use this equation:

$$cost\ of\ LPG = \frac{m_{LPG}}{m_{1\ cylinder}} \times cost\ of\ the\ cylinder \qquad (14)$$

$$cost\ of\ LPG = \frac{10458}{50} \times 45.96 = 8983.35\ JD$$

Table 4: Monthly savings by using geothermal energy.

Savings	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
LPG (JD)	8168.4	7001.5	5251.1	2333.8	2042.1	1458.6	1166.9	875.2	1458.6	583.5	4084.2	7001.5
Diesel (JD)	8983.4	7700.0	5775.0	2566.7	2245.8	1604.2	1283.3	962.5	1604.2	641.7	4491.7	7700.0

Now to find if using geothermal energy is lucrative it is desired to find the payback period of it. To do so we have first to assume an annual interest rate (i) that equals 7%. Also the initial cost of each method has to be included where it is approximately 20000 JD for geothermal and around 4000 JD as the cost for the boiler using LPG and Diesel fuels. The cash flow for the methods is shown in table (5) and figure (2) below.

Table 5: Cash flow of heating methods for nine months.

	Initial cost	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Geothermal	20000.0	20125.0	20250.8	20377.3	20504.7	20632.9	20761.8	20891.6	21022.2	21153.5
Diesel	4000.0	12193.4	19271.1	24642.7	27130.5	29342.2	30984.2	32344.8	33422.1	35089.7
LPG	4000.0	13008.4	20789.7	26694.6	29428.1	31857.9	33661.2	35154.9	36337.1	38168.4

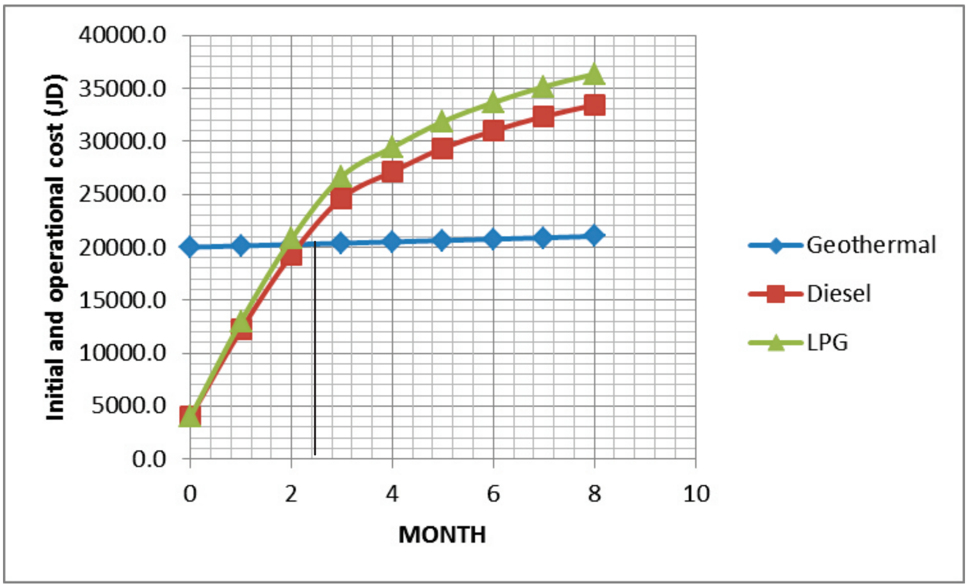

Figure 2: Comparison fo heating methods cash flows for nine month period.

5.Conclusion:

Looking at the results where the payback period is just a few months, it can be said that using geothermal water directly for heating purposes is tempting to cut the costs of high fuel consumptions. This means that farmers has to adopt this method even though the initial cost may be high at the beginning as this cost will be offset by the great savings of this method.

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