(Theoretical Study of Geothermal Energy as Sustainable Heating Solution for 'Jaref' Elementary School)

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Abstract: This study theoretically examines the geothermal energy resource as sustainable environmentally friendly renewable energy sources and energy source for the heat production using it in domestic practice. This paper illustrates the methods and the principles of operation of a geothermal energy from Jaref's Well that potentially produces thermal energy for utilizing it in heating system in Jaref elementary school in extremely cold winter time; in addition, an analysis of the methods. These allow implementing the proposed project in the field of domestic heating with sustainable geothermal energy is approved and presents the benefits of utilizing geothermal energy in this application.

This work is mainly based on real hot well data measured on the wellhead in Jaref area such as temperature (70^{o}C) and volumetric flowrate (2.5 kg s^{-1}) and well's specifications, which has the potential to allow conducting domestic theoretical study of using geothermal heating systems for the well's surrounding elementary school. Moreover, the work is based as well on some calculations for heat losses and examine the current fabric contributing in the targeted building in term of the heat isolation efficiency. These calculations' results show, the school windows and door have the majority of heat loss within the system which 71%. These require further consideration such as replacing the current windows glass with double glazing windows. Thermal resistance of the pipeline per meter was also calculated which is found to be 0.25 watts m^{-1}. However, when the well hot water flows in the pipeline, the heat loss is shows to be 6.825 watts m^{-1}. The amount of heat transferred through radiation for the single classroom and for the whole area is 242 watts. Eventually, this practice will allow the authors of the current study have pinched conclusions about the potential of presenting such technic in the targeted region. At the end of this paper, the focal conclusions based on the finding of the study are clearly provided.

Keyword: renewable energy, green heating system, sufficient energy use.

دراسة نظرية للطاقة الحرارية الجوفية كحل تدفئة مستدامة لمدرسة "جارف" الابتدائية.

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المستخلص: تبحث هذه الدراسة النظرية في مورد الطاقة الحرارية الأرضية (طاقة باطن الأرض) كمصدر طاقة متجددة مستدامة صديقة للبيئة ومصدر من مصادر الطاقة الحرارية لاستخدامها في الممارسة المنزلية. توضح هذه الورقة البحثية طرق ومبادئ تشغيل الطاقة الحرارية الأرضية من بئر جارف التي من ينتج طاقة حرارية لاستخدامها في نظام التدفئة في مدرسة جارف الابتدائية في فصل الشتاء شديد البرودة؛ بالإضافة إلى تحليل طرق استخدام هذه الطاقة. هذا يسمح بتنفيذ المشروع المقترح في مجال التدفئة المنزلية بالطاقة الحرارية الأرضية المستدامة ويعرض فوائد استخدام الطاقة الحرارية الأرضية في هذا التطبيق. يستند هذا العمل بشكل أساسي على بيانات الآبار الساخنة الحقيقية التي تم قياسها على فوهة البئر في منطقة جارف مثل درجة الحرارة (70 درجة

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مئوية) ومعدل التدفق الكتلي (2.5 كيلوجرام لكل ثانية) ومواصفات البئر، والتي لديها القدرة على السماح بإجراء دراسة نظرية محلية لاستخدام أنظمة التدفئة الحرارية الأرضية للمدرسة الابتدائية القريبة للبئر. علاوة على ذلك، يعتمد العمل أيضًا على بعض الحسابات الخاصة بفقدان الحرارة وفحص النسيج الحالي المساهم في المبنى المستهدف من حيث كفاءة العزل الحراري. تُظهر نتائج هذه الحسابات أن نوافذ المدرسة وأبوابها تتسبب في فقدان معظم الحرارة داخل النظام بنسبة 71%. وهذا يتطلب المزيد من الدراسة مثل استبدال زجاج النوافذ الحالية بنوافذ زجاجية مزدوجة. كما تم حساب المقاومة الحرارية لخط الأنابيب لكل متر والتي تبين أنها 0.25 واط م-1. ومع ذلك، عندما يتدفق الماء الساخن في خط الأنابيب، يتبين أن فقدان الحرارة يبلغ 6.825 واط م-1. وتبلغ كمية الحرارة المنقولة من خلال الإشعاع للمنطقة بأكملها 242 واط. في النهاية، ستتيح هذه الممارسة لمؤلفي الدراسة الحالية التوصل إلى استنتاجات حول إمكانية تقديم مثل هذه التقنية في المنطقة المستهدفة. في نهاية هذه الورقة البحثية، يتم تقديم الاستنتاجات المحورية المبنية على نتائج الدراسة بوضوح.

الكلمات المفتاحية: الطاقة المتجددة، نظام التدفئة الأخضر، استخدام الطاقة البديلة.

INTRODUCTION:

Obviously, geothermal energy as renewable energy source has gained attention as a sustainable heating solution for buildings. The utilization of the geothermal energy as a sustainable heating solution for buildings has been the subject of extensive theoretical study. (Vorsatz and Herrero, 2012) showed that geothermal energy sourced by the heat stored underneath the Earth's shell to sustainably provide heating or/and cooling for buildings. The proposed energy is derived from the natural heat in the earth's inner core, which is linked to the earth's internal system and physical processes. By tapping into the earth's geothermal heat, buildings can be heated efficiently and sustainably, reducing the reliance on fossil fuels and decreasing greenhouse gas emissions. Moreover, geothermal energy has the potential to provide a constant and reliable heat source, as the earth's thermal heat is continuously replenished. Several energy-related problems affecting human health and productivity take place in buildings, including mortality and morbidity due to poor indoor air quality or inadequate indoor temperatures. Improving buildings and their equipment by implementing geothermal energy as a sustainable heating solution can address these challenges. Green building practices, including the use of geothermal energy for heating, are crucial in addressing the energy and environmental issues that affect our world (Wang et all., 2012). Geothermal energy offers several advantages as a sustainable heating solution for buildings, it is considered as a free sustainable energy source and requires no pumping facilities to be produced.

Geothermal Energy Historical Background

Geothermal energy has been used for heating purposes since ancient times. (Gerbrlova et all., 2020) Since early times, societies having been utilizing this energy source for having bath, heating houses, preparing hot meal and nowadays this is also utilized for generating green electricity. (Kashif et all., 2023) renewable energy sources such as heating using biomass, cooking, lighting; and wind energy for sailing and wind turbine energy for driving mills; lastly hydro-power, was also utilizing for driving mills, which were the only available energy sources before the introducing of fossil polluted fuels. The huge-scale move to non-renewable energy sources initiated in the 1700s with the global industrial revolution, marking the rise of factories and a reliance on coal and later oil for heating purposes. Geothermal energy has been utilized for heating purposes since ancient times. Geothermal energy has a long history of being used for heating purposes, with ancient civilizations utilizing this energy source for activities such as bathing, heating homes, and preparing food. Geothermal energy has been a reliable source for heating purposes throughout history, dating back to ancient civilizations who used it for activities such as bathing, heating homes, and preparing food. Geothermal energy has a rich historical background in providing heat, with ancient civilizations utilizing it for activities like bathing, heating homes, and preparing food.

Paper’s Aims and Objectives

The main aim of this paper is to theoretically offer well-utilization of the geothermal energy source located in Jaref area to sustainably heat the Jaref elementary school, which is located about 100 m away from the heating source. Based on real measured data of temperature and volumetric flowrate, some calculations will be made to estimate the capacity and the performance of the proposed heating system.

LITERATURE REVIEW (GEOTHERMAL ENERGY AS A HEATING SOURCE)

Geothermal energy has gained attention as a sustainable and renewable energy source for heating applications. This literature review aims to synthesize and integrate research findings on the direct utilization of geothermal energy, its environmental impact, and its role in renewable energy systems.

Direct Utilization of Geothermal Energy

(Lund and Tóth, 2020) provide a comprehensive review of the official utilization of geothermal energy internationally. The study highlights the increasing trend of utilizing geothermal energy for heating applications. The authors emphasize the potential of geothermal energy as a sustainable heating source, which is crucial for addressing energy security and environmental concerns.

Environmental Impact of Geothermal Energy

(Rahman et all., 2022) conducted a study on the environmental impact of various renewable energy sources, including geothermal energy. The findings suggest that geothermal energy-based power plants have minimal environmental impact compared to other renewable energy sources. This underscores the potential of geothermal energy as a low-impact heating source, contributing to environmental sustainability.

(Sayed et all., 2020) conducted a critical review on the environmental impacts of renewable energy systems, including geothermal energy. The study emphasizes the importance of mitigating the environmental impacts of renewable energy sources. The authors highlight the need for further research on mitigating strategies specific to geothermal energy to ensure its sustainable utilization for heating purposes.

Role in Renewable Energy Systems

(Vera et all., 2019) discuss the role of geothermal energy in micro grids with renewable energy sources. The study highlights the potential of geothermal energy as a reliable heating source within micro grid systems. The authors underline the importance of integrating geothermal energy into renewable energy systems to enhance energy management and overall system efficiency.

JAREF HOT WATER WELL DESCRIPTIONS

It is located in the southwest of Sirte city in well-known agricultural wide valley called Jaref Valley. The hot water well was established in 1980 about 100 m away from two floors 12 classes Jaref elementary school. The well depth is 1820 m water temperature is about 70^{o}C, flowrate G about 5 kg/s. The well is connected by a pipe diameter 0.05 m of corrosion resistance of precision pipes and connectors made of a high quality pipe material of stainless steel. Figure 1 shows the head wellhead location, piping and fittings.

Figure 1, Jaref Hot water Well

SCHOOL LAYOUT AND BUILDING DESCRIPTION

The school was built in 1990 on total area of 4000 m^2 of a horseshoe shape two floors building and several surrounding play areas, 12 running students classrooms, the single classroom dimensions 20 m^2 and 3 m roof height, and 2.5 m^2 door area. The classroom has been provided with two external windows in area of 2 m^2 each for ventilations and natural lighting. Figure 2 illustrates the Jaref elementary school.

Figure 2, Two Floor Building of Jaref Elementary School

Obviously, the climate in this region is considered as a close environment to Sahara whether where it is very cold during the night and early morning from December to mid-February when the temperature can reach as low as 5°C. The figure 3 shows the last year temperature in area close to Jaref region and it should be similar to our targeted area (Jaref).

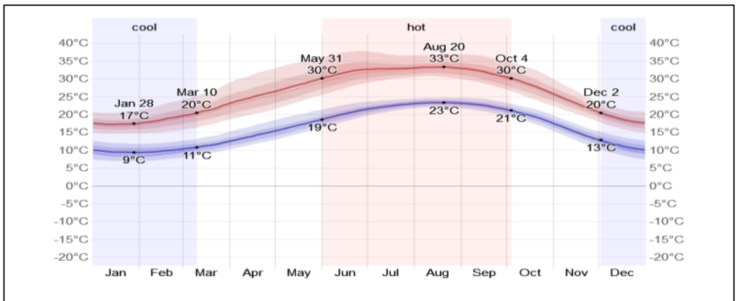

Figure 3, last year temperature in area close and similar environment of Jaref taken from (weather-spark oct 2024)

SCHOOL BUILDING THERMAL PROPERTIES AND MATERIALS

Basically, the Libyan standard building bricks are concrete hollow bricks in different sizes and geometry, however, the 20cm bricks are well-known and used in majority of Libyan constructions as shown in the figure. Additionally, in term of heat transfer, this kind of bricks has two processes of heat transfer conduction and convection. Obviously, the conduction heat transfer occurs through the solid part of the bricks, whereas, the convection heat transfer occurs through air cavities of the hollow bricks. These building materials are considered as inefficient insulation materials and design (Salem et all., 2023).

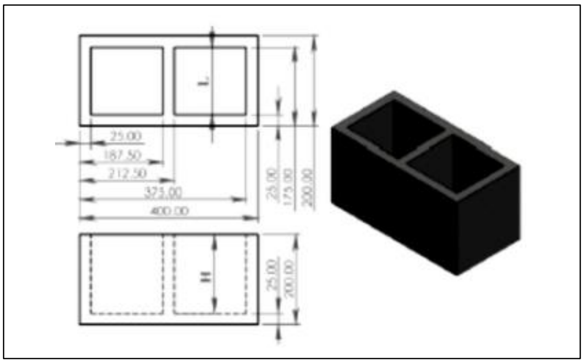

Figure 4, Geometric configurations of the hollow bricks 20 cm, taken from (Salem et all., 2023).

THE TEMPERATURE DROP ΔTS THROUGHOUT THE HOT WATER PIPE-LINE

As it is being mentioned earlier that through the heat transport pipe line between the wellhead to the school is 100 m distance. Its temperature drops ΔTs, The assumed pipeline diameter is DN = 0.050 m, initial temperature T_i = 70 °C (343.15K), mass flow rate G = 4.5 kg s^{-1}, surrounding temperature in early hours winter time T_s = 5 °C (278.15K), insulation thickness δ = 0.050 m and its thermal conductivity λ = 0.10 W m^{-1} K^{-1}. Figure 5 illustrates the diagram of heat transport pipeline with insulation is schematically and configuration.

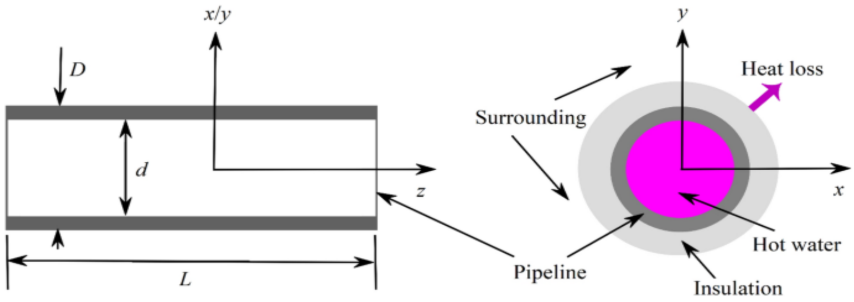

Figure 5, Pipeline diagram of water heat transport, adopted from (Wang, 2022).

Table 1 illustrates our hot water pipeline from the wellhead to the school, the proposed stainless steel diameter and Jaref hot water well measured parameters and the proposed pipe insulation and surrounding temperature.

Table 1: The Essential Parameters Selected

Stainless Steel Pipeline Diameter	
DN (m)	0.05
d (m)	0.05
D (m)	0.052
Well Hot Water Parameters	
T_i (K)	343.15
ρ (kgm^{-3})	978.2
v (ms^{-1})	1.28
Pipe Insulation and outside Temperature	
δ (m)	0.02
λ ($wm^{-1}K^{-1}$)	0.02
T_s (K)	278.15

Based on (Yang, 2006), the thermal resistance of pipeline per unit length, or is called as the thermal resistance per meter, can be expressed as:

$$R = \ln[(D + \delta)/D] / 2\pi\lambda = 2.59 \text{ Kwatt}^{-1}$$

The thermal resistance of the heat transport pipeline is:

$$R_{dL} = \ln[(D + \delta)/D] / 2\pi\lambda dL = R/dL = 2.59/100 = 0.0259 \text{ Kwatt}^{-1}\text{m}^{-1}$$

Then the heat loss across the differential amount length dL, which comes from the hot water within the pipeline and releases into the surrounding, can be determined from the equation:

$$d_Q = T - T_s / R_{dL} = (T_i - T_s / R)\, dL = (343.15 - 278.15/2.59)*100 = 0.25\text{watts m}^{-1}$$

When the well hot water is flowing through the pipeline, the heat loss, which caused by the hot water temperature drop across the same differential amount length dL as above, can be written as:

$$d_Q = C_pGdT = 4.20 * 2.5 * 65 = 682.5 \text{ watts} = 6.825 \text{ watts m}^{-1}$$

As specific heat is $C_p = 4.20$ kJ kg^{-1} K^{-1}, and the measured G is 2.5 kgs^{-1} and dT is different temperature $(T_i - T_s) = 65°C$.

CALCULATING THE TOTAL HEAT REQUIREMENT FOR THE CLASSROOM

In order to determine the heating load of a classroom, the amount of heat loss from the structure need to be calculated. This can be done by considering factors such as the building's insulation, air leakage, windows and doors, and the difference in temperature between the inside and outside.

Additionally, to calculate the total heat requirement of the school classroom you would typically consider factors such as the building's size, insulation, location, climate, and the desired indoor temperature. The formula for calculating heat requirement is:

Heat Requirement = (Building Area) × (U-value) × (Temperature Difference) / (Heating System Efficiency)

- Building Area: The total surface area of the building's walls, roof, windows, and floor.
- U-value: A measure of the building's insulation; lower values indicate better insulation.
- Temperature Difference: The alteration between the desired indoor temperature and the mean outdoor temperature.
- Heating System Efficiency: The efficiency of the heating system being used.

Keep in mind that this is a simplified explanation, and actual calculations might involve additional considerations. It is recommended to consult with a heating and cooling professional or use specialized software for accurate results.

CALCULATING THE TOTAL HEAT LOSS OF THE SCHOOL CLASSROOM

Initially, the dimensions of the school classroom are illustrated in the figure 1, which are 12 classroom utilized by students in the school. One classroom is taken as prototype to start with and then the same procedure is implemented on all school’s classrooms.

As the targeted building is an elementary school in region of Jaref, the U-values of the whole elements of the exterior material of a building, its volume and its mean ventilation ratio are acknowledged. the calculation of whole heat loss coefficient would be clearly obtained, this can be illustrated as the total space heating energy flow rate in watts divided by the temperature change or difference between the inside and outside air.

So, the entire material involvement in the total heat loss coefficient can be obtained as follow:

$$Q_f / \Delta T = \Sigma U_x A_x \text{ W K}^{-1}$$

The complete material heat loss flow rate, Q_f, will be the sum of all the U-values of the individual elements of the external used material, floor, walls, windows, roof, and doors multiplied by their particular regions multiplied by the internal and external change in temperature, ΔT as follows:

$$Q_f = (\Sigma U_x A_x) \times \Delta T \text{ watts}$$

Based on real data gained from Jaref elementary school such as classroom area, windows area and classroom volume. Ventilation of the class room is assumed compared with the literature. Based on real gathered data from the school in term of the classroom areas, this is calculated in the table 2:

Table 2: Classroom materials elements and heat losses

Element	Area/ m^2	U-value/ watts $m^{-2}K^{-1}$	Contribution to heat loss coefficient/ watts K^{-1}
Floor	20	0.5	10
Roof	20	0.3	6
Walls	15	0.7	10.5
Windows and doors	6.5	4	26
Ventilation			10

The ventilation heat loss can be included, as follow:

- $Q_v = 0.33 \times n \times V \times \Delta T$ watts

Where n is the air changes number hourly (ACH) and V is the dimensions of the classroom (m^3).
The contributing ventilation to the whole coefficient of heat loss is:

- $Q_v / \Delta T = 0.33 \times n \times V$ watts K^{-1}

Assumingly, a change rate of air is 0.5 ACH (which involves practically airtight civil engineering structure) and taking the classroom volume of as 60 m^3:

- $Q_v / \Delta T = 0.33 \times 0.5 \times 60 = 10$ watts K^{-1}

Adding the material and contributing ventilation provides a total coefficient of the whole-classroom heat loss:

- $(Q_f + Q_v)/\Delta T = 79.8 + 10 = 89.8$ watts K^{-1}

Figure 6 shows the breakdown percentage of the losses, which demonstrates their relative significance and provides a evidence as to places to investigate for further improvements. As a result the windows and doors heat loss play a crucial effect as it has the majority of the heat loss in the system which 71%.

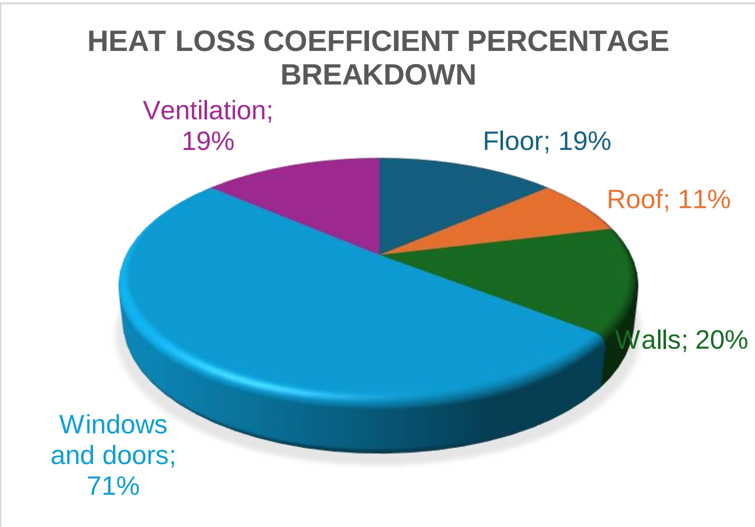

Figure 6, Percentage Breakdown of Heat Losses

DETERMINE THE HEAT EXCHANGERS IN THE CLASSROOMS

The first suggestion on installing the heat exchangers is to locate two heat exchangers right under each window of the two classroom windows fixed on the internal classroom wall. The wall area under the two windows is enough to accommodate these heaters. However, the selection of a heat exchanger for a school classroom heating system is crucial to the system's overall efficiency and performance.

School classroom heat loss coefficient can be estimated a appropriate dimension for the heating system. If it is assumed an internal temperature of 20°C (293.15 K), the average winter external temperature of the mentioned region is 5°C (278.15 K), then the proposed heating system required to conserve a temperature difference of 15°C (288.15 K).

In order to approximate of the required heating system, Q_h, which can be calculated as:

- $Q_h = 288.15 \times 89.8 = 25875.87$ watts

As a result, the insulation plays crucial role in the heating system efficiency, better and efficient insulation in the system, the smaller and inexpensive the suggested heating system would be.

According to the available hot water well data, as the water temperature is 70^{o}C and the internal classroom temperature in the winter time is 5^{o}C, the following calculations are used to determine the radiation heat transfer.

Temperature of hot body, T_{Hot}= 343.15 K

Temperature of cold body, T_{Cold} = 278.15 K

Change in temperature, $(T_{Hot} – T_{Cold})$ = 343.15-278.15= 65 K

Area of the classroom, A = 20 m^2

Stefan Boltzmann Constant, σ = 5.67 x 10^{-8} $W/(m^2K^4)$

Using the heat transfer formula for radiation,

$Q_r = \sigma (T_{Hot} - T_{Cold})^4 A$

$Q_r = 5.67 \times 10^{-8} \times (343.15\text{-}278.15)^4 \times 20$

Q_r = 20 watts

Therefore, amount of heat transferred through radiation is 20 Watts for single classroom. However, the total classrooms areas would be calculated as 20 x 12= 240 m^2

It is assumed that there is no wall between these classroom to simplify the heat transferred through radiation calculation, the overall heat transfer for radiation for the whole area would be as it follows:

$Q_r = 5.67 \times 10^{-8} \times (343.15\text{-}278.15)^4 \times 240 = 242$ watts

RESULTS AND DISCUSSIONS:

By conducting an analysis of the previous part calculation results, it obvious that there is a potential of geothermal as renewable energy utilization in Jaref zone to use it as energy resource in classroom heating system. Through analysing the thermal properties of the school building materials, calculating the heat load of the school building, and determining the heat exchange rate, we could design an efficient and effective heating system that relies on renewable geothermal energy located close to the targeted school. With the right calculations and a commitment to sustainability, we can reduce our carbon footprint and create a more environmentally friendly way to heat our school classrooms.

It is worth mentioning that the return water (cold water) from the heating system (open loop) will be return to a created new well. This will prevent creating a giant lake on the land surface because of cold return water from the school.

CONCLUSION:

In the present work, setting up a sustainable heating system for the school building using nearby geothermal energy source (Jaref’s well) requires careful calculations and considerations and critical analysis. Through analysing the thermal properties of the school building materials, calculating the pipeline heat losses 100 m distance between the wellhead and school.

Based on the calculation results, the school windows and door have the majority of heat loss within the system which 71%. These require further consideration such as replacing the current windows glass with double glazing windows. Thermal resistance of the pipeline per meter was calculated which is found to be 0.25 watts m^{-1}. However, when the well hot water flows in the pipeline, the heat loss is shows to be 6.825 watts m^{-1}. The amount of heat transferred through radiation for the single classroom and for the whole area is 242 watts.

As result of the previous calculations and a commitment to sustainability energy use, these can reduce the carbon footprint and create environmentally friendly way to heat Jaref elementary school classrooms.

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NOMENCLATURE:

Symbols	Definition & units	Symbols	Definition & units
δ	Pipeline insulation thickness (m)	L	Pipeline length (m)
d	Pipeline inner diameter (m)	dL	A differential length (m)
D	Pipeline outer diameter (m)	T	Temperature of the hot water (°C)
DN	Pipeline nominal diameter (m)	T_i	Initial temperature of the hot water (°C)
λ	Insulation thermal conductivity (W m^{-1} K^{-1})	T_s	Surrounding temperature (°C)
Dcr	Critical insulation diameter (m)	dT	A differential temperature increment (°C)
T_{Hot}/ T_{cold}	Temperature of hot/cold body (°C)	d_Q	Heat loss cross the differential amount (watts)
G	Mass flowrate (kg/s)	Cp	Special heat at constant pressure (J kg^{-1} K^{-1})
h	Convective transfer rate (W m^{-2} K^{-1})	Q	Heat loss across the pipeline length (kJ s^{-1})
v	Flow velocity ms^{-1}	ρ	Fluid Density kgm^{-3}
R	thermal resistance per meter	R_{dL}	Thermal resistance of the heat transport pipeline
π	A constant with a value of (3.14)	Q_a	Available thermal energy (kJ s^{-1})
U-value	Measure of building's insulation (w m^{-2} K^{-1})	A	Area m^2
ΔT	Temperature difference	Q_f	Complete material heat loss flowrate watts
Q_v	Ventilation heat loss (watts)	n	The air change number hour (ACH)
V	Volume (m^3)	Q_h	Required heating system (watts)
σ	Stefan Boltzmann (w/m^2K^4)	Q_r	Heat transfer radiation formula (watts)

REFERENCES:

Gerbelová Hana, Amanda Spisto & Sergio Giaccaria, 2020. "Regional Energy Transition: An Analytical Approach Applied to the Slovakian Coal Region," Energies, MDPI, vol. 14(1), pages 1-24, December.

Kashif Md, Gohar Deshmukh, Mohd Sameeroddin, Daud Abdul, Mohammed Abdul Sattar , 2023, Renewable energy in the 21st century: A review, Volume 80, Part 3, 2023, Pages 1756-1759 sciencedirect.
https://doi.org/10.1016/j.matpr.2021.05.501

Lund, J., & Tóth, Anikó N.. (2020). Direct utilization of geothermal energy 2020 worldwide review of Geothermic.

http://doi.org/10.1016/j.geothermics.2020.101915
Rahman Farrok, Haque Rahman, Abidur., Farrok, Omar., & Haque, M. (2022). Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic. Renewable and Sustainable Energy Reviews.
http://doi.org/10.1016/j.rser.2022.112279
Salem Mohamed, Khaled M. Sultan And Elfaitori Ibrahim, 2023, Numerical Study Of Thermal Behavior Of Concrete Bricks Used In Libya Using Ansys Software, Journal of Engineering Research, University of Tripoli, issue 36, September 2023.
Sayed, E., Wilberforce E., , Elsaid T., , Khaled., Rabaia, Malek Kamal Hussien., Abdelkareem, M.., Chae, K.., and Olabi, A., (2020). A critical review on environmental impacts of renewable energy systems and mitigation strategies: Wind, hydro, biomass and geothermal. The Science of the total environment, 766, 144505.
http://doi.org/10.1016/j.scitotenv.2020.144505
Vera, Y. E. García., Dufo-López, R.., and Bernal-Agustín, J.. (2019), Energy Management in Microgrids with Renewable Energy Sources: A Literature Review. Applied Sciences.
http://doi.org/10.3390/app9183854
Vorsatz D Ürge, Herrero ST., 2012, Building synergies between climate change mitigation and energy poverty alleviation- Energy policy, 2012 – Elsevier.
Wang Deming, 2022, Heat Loss Along The Pipeline And Its Control Measures, SN Applied Sciences, Springer Nature Journal, December 2022.
https://doi.org/10.1007/s42452-022-05226-2
Wang Jia, Haibo Jia, Hui Wang 2012, Advanced materials research, 2012.
Weather spark website https://weatherspark.com, accessed June - 2024.
Yang S (2006), Heat Transfer, 2nd Edition. Higher Education Press, 2006, Beijing.