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Cost Comparison of Using Geothermal Energy and Natural Gas for Domestic Space Heating in Meshkin Shahr, Iran

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ABSTRACT

About 80% of the fluid produced by geothermal wells in Sabalan is liquid and not used by single flash cycle for electricity generation. One of the appropriate options to utilize the energy of liquid phase of geothermal fluid in Sabalan can be direct use as domestic space heating. In this research an under Construction Residential Complex selected in Meshkin Shahr and required energy for its central heating has been calculated. The cost of the energy supply in a trial period by geothermal energy and natural gas was compared. Mathematical models for space heating were developed and implemented in the Carrier 99 software.

1. INTRODUCTION

There are many direct use applications that are able to use lower temperature geothermal fluids (e.g. 50 100°C range) that are unsuitable for electricity generation and which are much more prevalent world-wide than moderate- or high-temperature systems. Geothermal space heating is extensively used in Europe (particularly Iceland and France), the USA, China, Japan and Turkey. For space heating, hot geothermal water is either circulated directly through the buildings or is used as a heat source for a separate closed-loop heating system, depending on available temperature, flow and water quality. A wide range of resource temperatures can be used, but the most common range would be 50-80°C.

The Mt Sabalan geothermal field is located in the Moil Valley on the northwestern flank of Mt Sabalan, in the Azerbaijan region of Northwest Iran. Access to the area is provided by a sealed road from the nearby town of Meshkin Shahr to the village of Moil, then to the valley south of the village by an unsealed road. The resource has now been proven by the encouraging results from the initial three deep well exploration drilling program and the results have led to consider further delineation and development drilling in the geothermal resource area, as well as options for early development. The currently confirmed geothermal resource capacity at the NW Sabalan geothermal prospect is between 20 and 40MWe. Moreover there is an overall potential for the generation of some 200 MWe of electricity over the greater prospect area. Since total distance from Sabalan geothermal field to the nearest town, Meshkin Shahr is almost 16 km, one of the appropriate options to utilize the energy of liquid phase of geothermal fluid can be direct use as domestic space heating in Meshkin shahr (Iran Ministry of Energy, 2005). However, there is not any serious survey in economical feasibility of that so far.

This research, considering the current domestic heating system in Meshkin Shahr is Natural Gas piping system, has made a cost comparison between Natural Gas and geothermal energy using as domestic heating system. That is, required energy for central heating of under construction residential complex selected in Meshkin Shahr and the cost of needed Natural Gas for six months has been estimated. Then, using the result as a criterion the economical feasibility of geothermal energy using in domestic heating has been discussed.

2. HEATING LOAD CACULATION

Variations in the characteristics of residences can lead to surprisingly complex load calculations. Time-varying heat flows combine to produce a time-varying load. The relative magnitude and pattern of the heat flows depends on the building characteristics and exposure, resulting in a building-specific load profile. In general, an hour-by-hour analysis is required to determine that profile and find its peak.

In theory, cooling and heating processes are identical; a common analysis procedure should apply to either. Acceptable simplifications are possible for heating; however, for cooling, different approaches are used. Heating calculations use simple worst-case assumptions: no solar or internal gains, and no heat storage (with all heat losses evaluated instantaneously). With these simplifications, the heating problem is reduced to a basic $UA\Delta t$ calculation (ACCA. 2003). Figures 1, 2 and 3 in appendix1 show the selected residential complex plan. The complex divides in tow sites, A and B which sequentially consists of 3 and 5 blocks. Each block similarly is in five residential floors and an underground as a parking that each floor has two apartment units. The similarities of blocks allows estimating total heating load for the complex with an reasonable approximation by only one block's calculation, then, multiplying it by 8. In this research the heating load has been calculated manually and the result has been verified by Carrier software.

The needed heating energy for a residential building consists of heat losses and heat of consuming hot water. Calculating a heating load involves estimating the maximum heat loss of each room or space to be heated and the simultaneous maximum heat loss for the building, while maintaining a selected indoor air temperature during periods of design outdoor weather conditions (ACCA. 2003).

2.1 Heat Losses Calculation

Heat losses which should be compensated by heating equipments such as heater, radiator and fan coils, etc. occurs in two ways in a building: heat transfer by conduction through walls, roof, floor, doors and windows (Q_1) and by air displacement while the doors or windows are opening and also through blowholes in convection (Q_2).

Q_1 is calculated as follows:

$$Q_1 = AU(t_{in} - t_{out}) \quad (1)$$

where Q_1, A, U, t_{in}, t_{out} are transferred heat by conduction thorough the walls, roofs, etc in W, area of walls, roofs, etc in m^2, overall heat transfer coefficient in W/m^2 °C, indoor design temperature °C, outdoor design temperature in °C.

Table 1 show the outdoor weather condition and Indoor design temperature based on meteorological reports and table 2 shows the building materials details and their overall heat transfer coefficient (U) (ASHRAE Air Conditioning Handbook, 2001).

Table 1: The outdoor weather condition and Indoor design temperature.

description	*value*
City name	Meshkin shahr
Latitude deg.	35.7
Longitude deg.	- 47
Elevation (m)	1800
Summer design dry- bulb	30 °C
Summer coincident wet-bulb	20 °C
Winter design dry-bulb	-7.8 °C
Winter design wet-bulb	-15 °C
Atmospheric clearance number	1.00
Average ground reflectance	0.2
Soil conductivity	1.385 W/m/k
Indoor design temperature	22 °C
Local time zone (GMT +- Hours)	+3.5

Table 3 in appendix 2 shows the heat losses calculation of a living room in eastern apartment unit in floor 3 as a sample. The value of $Q_{1,sample} = 2883.97$ W was found for the sample room as shown in table 3 in appendix 2. In the same way, it is calculated for all rooms and spaces in a block and the final result for a block is gained by the sum total of them which was found to be $Q_{1,total} = 110.7 KW$.

Then, the transferred heat via convection by displaced air while the doors or windows are opening and also through blowholes, Q_2 , is calculated as follows:

$$Q_2 = V \times 0.0749 \times 0.241 \times 0.293 \times (t_i - t_o) \quad (2)$$

where Q_2 , V, 0.0749, 0.241, 0.293, t_i, t_o are transferred heat via convection by displaced air in W, displaced air volume in CFH, air density in standard condition in lb/ft^3, specific heat of the air in constant pressure in Btu/lb.F, conversion coefficient of Btu/hr to W, indoor design temperature in °F, outdoor design temperature in °F.

While V is calculated as:

$$V = v \times n \quad (3)$$

where v, n are volume of the specified room in ft^3, coefficient of air displacement times which for this research case is equal to 1.5

Table 2: The building materials details and their overall heat transfer coefficient (U).

	materials	**Heat transfer coefficient (W/m^2 C)**
Wall	Gypsum plaster(3cm), common brick(30 cm), stone facing (2cm)	1.76
Roof	Asphalt roll roofing, cinders, brick, sand gypsum plaster	0.782
Floor	Sand, floor tile, concrete	0.163
Doors	Wooden	2.5
Windows	Duplex glasses	3.2

Using the equations (2) and (3) for sample room gains the results below:

$$v = 6 \times 7.3 \times 3 = 131.4 \text{ m}^3 = 4485.08 \text{ ft}^3$$

$$V = 4485.08 \times 1.5 = 7027.62$$

So,

$$Q_2 = 7027.62 \times 0.0749 \times 0.241 \times 0.293 \times (72 - (18))$$

$$\Rightarrow Q_{2,sample} = 2007.1 \text{ W}$$

In the same way, it is calculated for all rooms and spaces in a block and the final result for a block is gained by the sum total of them which was found to be $Q_{2,total} = 67.05 kW$.

2.2 Heating Load Calculation of Consuming Hot Water

In order to heating load calculation of consuming hot water, firstly should have the required temperature and quantity of hot water. Depending on consumption case, the hot water temperature can be different. In domestic consumption the temperature of hot water should be 60 °C (140 F) at least, while the inlet water temperature in Meshkin Shahr according to local meteorology reports is about 5° C (41 F).

To specify the real amount of consuming hot water in a building, its maximum consumption and demand factor should be known. Since the hot water does not consume in all hours and also all of related equipments are not used at the same time, the demand factor should be defined to specify exact amount of needed hot water. That is;

$$C_{real} = C_{\max.} \times F_d \quad (4)$$

where C_{real} , $C_{\max.}$, F_d are real hot water consumption in GPH, maximum hot water consumption in GPH, demand factor.

The maximum consumption and demand factor of hot water for an apartment unit is prepared as standards (ASHRAE Air Conditioning Handbook, 2001) by values of;

$C_{\max.}$ = 10 GPH per person

F_d = 0.6

On the assumption that 5 person live in each apartment unit, consequently real hot water consumption for a unit is obtained by:

$$C_{real} = 5\times10\times0.6 \Rightarrow C_{real} = 30 \text{ GPH}$$

Since there are 10 apartment units in every block, the total real hot water consumption for a block will be;

$$C_{real,total} = 300 \text{ GPH}$$

Following the calculation of needed amount of consuming hot water, its heating load is obtained by equation (5).

$$Q_{3,total} = C_{real,total}\times8.33\times0.293\times(t_2 - t_1) \quad (5)$$

where $Q_{3,total}$, $C_{real,total}$, 8.33, 0.293, t_2, t_1 are heating load of consuming hot water for a block in W, total real hot water consumption for a block in GPH, specific weight of water in lb/G, conversion coefficient of Btu/hr to W, consuming hot water temperature in °F, inlet water temperature in °F,

$$Q_{3,total} = 300\times8.33\times0.293\times(140-41)$$

$$\Rightarrow Q_{3,total} = 72.5kW$$

2.3 Total Heating Load

The total heating load of a block which is provided by boiler is sum of heat losses and hot water heating load that was found above. Moreover there is another heat loss in pipes and boiler that must be considered. Thus a reliability coefficient of 5% to 20% of calculated heating load, depending on pipe insulation quality, should be added to. Consequently

$$Q_{all} = (Q_1 + Q_2 + Q_3)\times(1 + A) \quad (6)$$

where Q_{all} , A, are total heating load of a block in W, reliability coefficient that is given by 10%.

Eventually

$$Q_{all} = (110.7 + 67.05 + 72.5)\times(1 + 0.1)$$

$$\Rightarrow Q_{all} = 275.3kW$$

No matter that what kind of heating system will be chosen for this complex, Q_{all} should be provided either by burning Natural Gas using boiler and burner or geothermal low temperature liquid using heat exchanger and so on.

3. REQUIRED NATURAL GAS

Required flow rate of the fuel which is burned in the burner (burners) to provide the heating load is gained from equation 7 (ASHRAE Air Conditioning Handbook, 2001).

$$W = \frac{Q_{all}}{K\times E} \quad (7)$$

where W, Q_{all} , K, E are needed flow rate of the used fuel in burner in m^3/s, total heating load of a block in kW, heating value of the fuel which is 40951.57 kJ/m^3 (9790 $kcal/m^3$) for natural gas, efficiency of the burner which is from 60% to 80% commonly, depending on burner quality, and is given by the value of 75% in this research.

Subsequently

$$W = \frac{275.3}{40951.57\times0.75}$$

$$\Rightarrow W = 0.009 \ m^3/s$$

Since the residential heating period in Meshkin Shahr is almost six month, from October to May, the required Natural gas amount is calculated for this trial period. To calculate the required natural gas volume in six month, it is necessary to estimate six month in second. Therefore

$$6(month)\times30(day / mounth)\times24(hour / day)$$
$$\times60(minute / hour)\times60(second / minute)$$
$$= 15552000 \text{ sec}$$

Consequently, the total required volume of natural gas for six month, B, is obtained:

$$B = 0.009\ (m^3/\text{sec})\times15552000\ (\text{sec})$$
$$\Rightarrow B = 139968\ m^3$$

3.1 Cost of the Required Natural Gas

Iran has the second largest gas resources in the world and also big oil resources. This situation makes the government subsidies the consuming fuels. Therefore, there are two prices about fuels to comparison with other alternative energies. One is the subsidized price and another is exportation price. Presently, the subsidized price of natural gas in Iran is 100 Rails, and the price for exportation is 690 Rials for a cubic meter (monthly delivered Gas bill) while a US Dollar is almost 10000 Rials. Subsequently the cost of the required natural gas, P, is to be:

$$P_{subsidised} = 139968\ m^3\times100\ (Rials / m^3)$$
$$\Rightarrow P_{subsidised} \approx 14,000,000\ Rials \approx 1,400\ US\ \$$$

$$P_{\exp ortaion} = 139968\ m^3\times690\ (Rials / m^3)$$
$$\Rightarrow P_{\exp ortation} \approx 96,500,000\ Rials \approx 9,650\ US\ \$$$

The obtained results are about only one block that multiplies them by 8 (the complex consists of the 8 similar blocks) gives the results for all complex. Thus

$$P_{subcidised\ ,complex} = 77,000,000\ Rials$$

$$P_{exportation\ ,complex} = 77,000\ US\ \$$$

4. COMPARISON AND DISCUSSION

The cost of natural gas, burning as heating fuel, can be a criterion to discuss the economical feasibility of geothermal energy use in domestic heating. As mentioned, although there is a great interest to use geothermal energy as direct use, there is no practical survey in its feasibility. In other words, to have starting point for geothermal energy use in domestic heating, it should be justifiable in comparison with other alternative fuels such as natural gas. By the way, considerable points are below:

- It has been assumed that the chosen central heating system for the complex is central heating with hot water, means that the geothermal liquid will be used as a heat source for a separate closed-loop heating system.
- Because the natural gas pipe is available for every residential building by a regulator valve beside main doors', it seems that the only needed piping for natural gas is from regulator to burner, while it is from geothermal field to central heating powerhouse, in other hand.
- In addition to running cost of natural gas, there are some differences in powerhouse equipping cost too. For example, it must be equipped with boilers and burners in using natural gas, but in using geothermal energy they can be omitted.
- From air pollution point of view, Natural Gas burning produces a lot of greenhouse gasses such as co_2 that it is almost zero about geothermal energy.
- All in all, no matter of the geothermal liquid temperature, it seems that the main cost of using geothermal energy in domestic heating is the piping and its insulation from geothermal field to powerhouse of the building. In contrast, it is the running cost in natural gas use.
- Regarding the total distance from geothermal field to the residential complex is 16 km, and also the cost of its heating, burning natural gas, by the value of 77000 US dollar in six month for one complex; it can be discussed that in what price it will be justifiable economically to have the piping done, or for how many residential complexes it will be justifiable, depending on preferences.

5. CONCLUSION

- The heating load of a residential complex selected in Meshkin Shahr, near to Sablan geothermal field has been calculated in KW.
- Choosing the hot water central heating system, the required Natural Gas flow rate and also its required volume to provide the heating energy of the complex due six heating months has been estimated respectively in m^3/sec and m^3.
- Regarding both exportation and subsidized price of Natural Gas in Iran the cost of selected residential complex heating due six months, burning natural gas, has been calculated in US dollar an Rial.
- Considering the facts that the main cost of using geothermal energy is the initial piping and insulation from geothermal field to powerhouse of the complex, and also it is the running cost for natural gas burning, the economical similarities and differences has been discussed.

NOMENCLATURE

Q_1	:Transferred heat by conduction thorough the walls, roofs, etc…, W
A	:Area of walls, roofs, etc…, [m^2]
U	:Overall heat transfer coefficient, [W/m^2. °C]
t_{in}	:Indoor design temperature, [°C]
t_{out}	:Outdoor design temperature, [°C]
Q_2	:transferred heat by displaced air, [W]
V	:displaced air volume, [CFH]
v	:Volume of the specified room, [ft^3]
N	:Coefficient of air displacement times
C_{real}	:Real hot water consumption, [GPH]
$C_{max.}$	:Maximum hot water consumption, [GPH]
F_d	:Demand factor
$Q_{3,total}$	:Heating load of consuming hot water for a lock, [W]
$C_{real,total}$	:Total real hot water consumption for a block, [GPH]
t_2	: Consuming hot water temperature, [°F]
t_1	: Inlet water temperature, [°F]
Q_{all}	: Total heating load of a block, [kW]
K	: Heating value of the fuel, [kJ/m^3 ($kcal/m^3$)]
E	: Efficiency of the burner
$P_{subsidised}$	:The cost of the required natural gas based on subsidized price.
$P_{exportation}$	:The cost of the required natural gas based on exportation price.

W :Needed flow rate of the used fuel in burner, $[m^3/s]$

CFH : Cubic foot per hour.

GPH : Gallon per hour.

REFFERENCES

ACCA.: Manual J residential load calculations, 8th Edition, Air Conditioning Contractors of America, Arlington, VA. 2003.

ASHRAE Handbook: Chap. 44, ‘‘Control of Gaseous Indoor Air Contaminants.’’ 1999 Applications.

ASHRAE Handbook Fundamentals, edition 2001.

Emeish, M.E.: Simulation of heating systems in Jordanian building. University of Iceland, M.Sc. thesis, UNU-GTP, Iceland, report 1, 2001.

Valdimarsson, P., District heating system: Fundamentals and application, paper presented at 6th National Heating, Ventilation, Air-Conditioning and Sanitary Congress and Exhibition, Turkey.

Valdimarsson, p.: Modeling of geothermal district heating systems, University of Iceland, PhD thesis, 1993.

APPENDIX 1

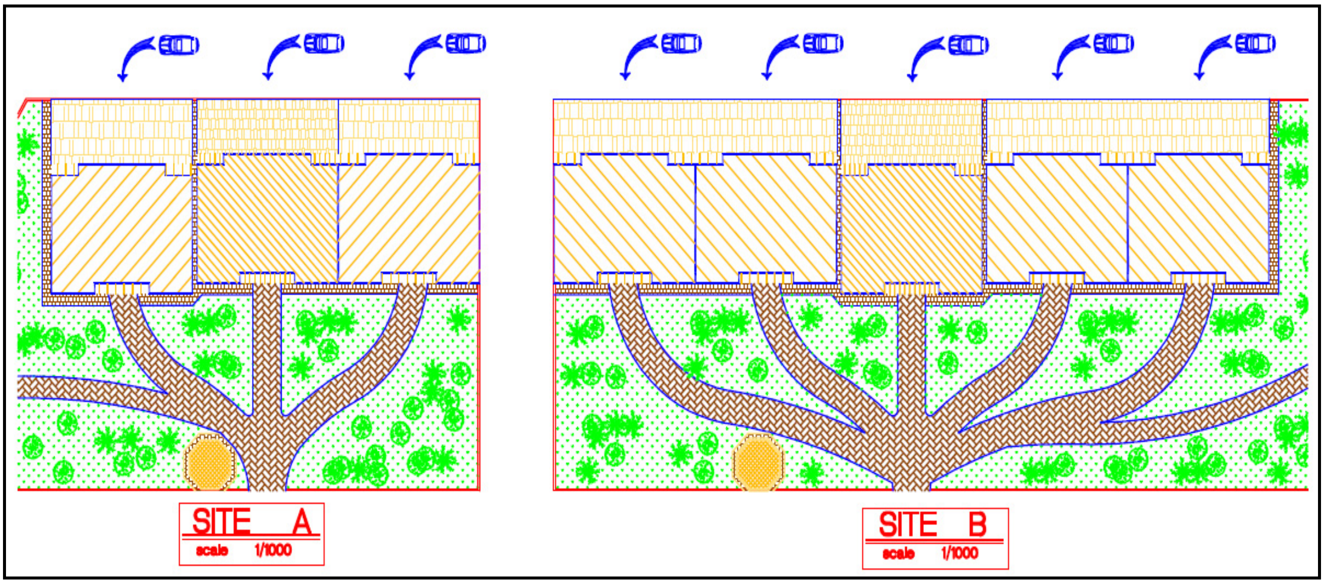

Figure 1: The complex divides in tow sites, A and B which sequentially consists of 3 and 5 blocks.

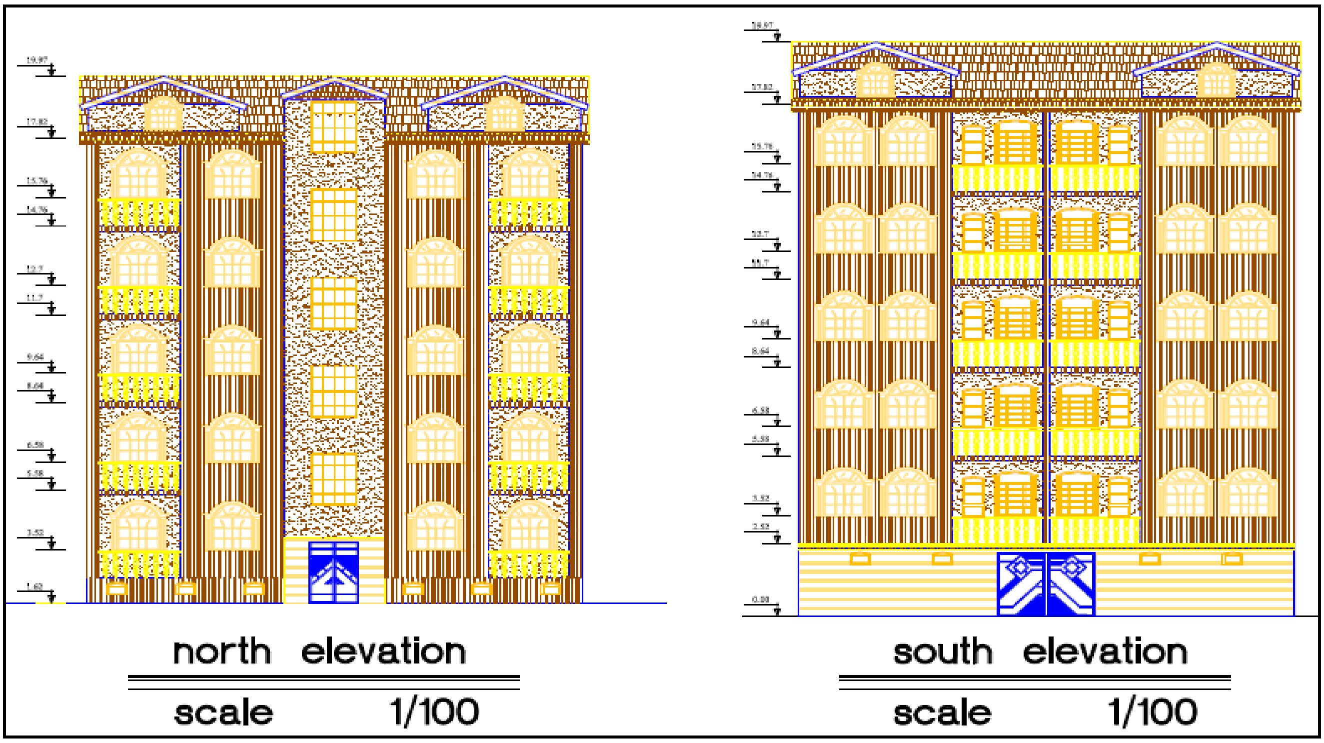

Figure 2: Each block similarly is in five residential floors and an underground as a parking.

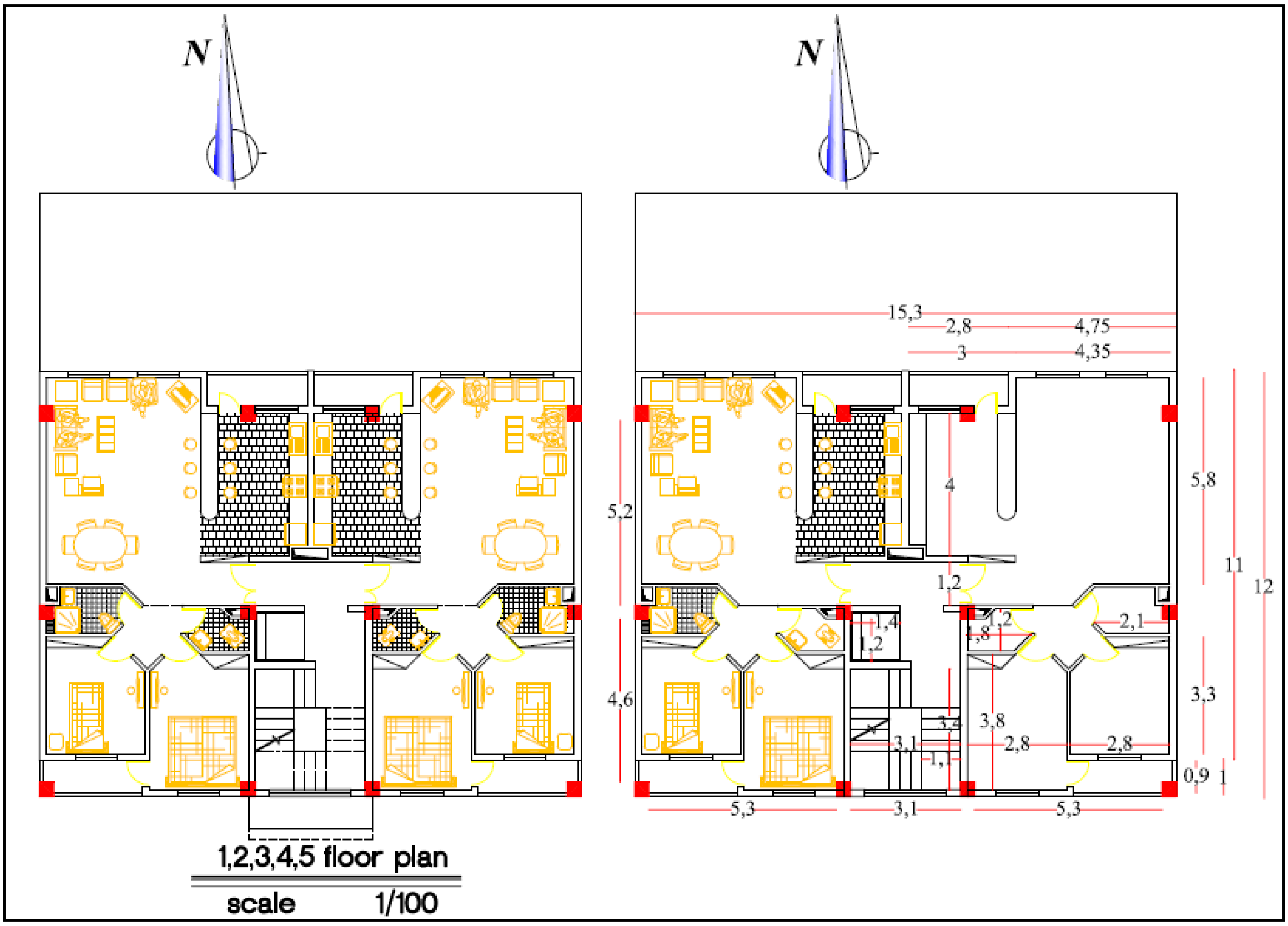

Figure 3: Each floor divides into two apartment units.

APPENDIX 2

Table 3: The heat losses calculation of a living room in eastern apartment unit in floor 3 as a sample

Walls	Length(m)	Height(m)	area(m^2)	U(W/m^2.°C)	$t_{in} - t_{out}$ (°C)	*Heat losses (w)*
Eastern wall	6	3	18	1.76	32	1013.76
Northern wall	7.3	3	21.9	1.76	32	1233.41
Southern wall	-	-	-	-	-	-
Window	3	1.5	4.5	3.2	32	460.8
Door	1.2	2.2	2.2	2.5	32	176
Floor	-	-	-	-	0	0
roof	-	-	-	-	0	0
sum						**2883.97**