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Feasibility of solar thermal collectors usage in dwelling apartments in Mashhad, the second megacity of Iran

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ABSTRACT

Today, the concept of net zero-energy buildings has become a major concern regarding fossil fuels combustion side effects, such as air pollution or global warming. Nonetheless, NG (natural gas) is a kind of fossil fuels which is widely combusted in Iran to meet various buildings heating demand. However, the objective of this study is mitigating NG flaring by substituting solar energy as an auxiliary energy source in dwelling buildings. To promote this idea a solar thermal collector is designed. This application is installed on the roof and is responsible to preheat either water circulates in radiators loop, to provide space heating, or domestic hot water to supply washing demand in residential apartments. Indeed, in case of utilizing this application fewer NG will be combusted for rising input water temperature to required value. This approach, consequently leads to decline CO_2 emission eventually. Also a dwelling complex including 136 flat apartments is taken into account to perform this research. This complex is situated in Mashhad, the second megacity in Iran. Besides, to evaluate this potential four steps have been taking into account. In the first step annual DHW (domestic hot water) load is computed. Second, heating load is achieved according to actual NG consumption (the sole energy source in case study). In the third step the net annual energy which can be gain by solar absorber is calculated. Finally, annual NG economy, invest return time of solar collector and CO_2 avoided are evaluated 203,000 m^3, 4 yr and 380 t/yr, respectively.

Contents

1. Introduction

Undoubtedly, energy is an essential requirement and basic need for continuity of development particularly in industrial societies and plays a pivotal role in human welfare. As these societies grow the amount of energy usage grows as well. The building sector consumes about 40% of annual energy in Iran and has considerable portion in energy demand [1]. Fossil fuels have still the lion share of energy marketing. Iran is a well-known country in terms of either producing or consuming hydrocarbon fuel resources including Natural Gas or Crude Oil [2]. NG(natural gas) network is widely distributed among several cities of Iran and is responsible to meet heating demand for various building

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Nomenclature

I_b	clear sky beam radiation (MJ/m^2 h)
I_d	clear sky diffuse radiation (MJ/m^2 h)
A_c	collector area (m^2)
T_i	liquid inlet temperature in collector tube (°C)
T_a	ambient temperature (°C)
$h_{c,p-c}$	convection coefficient between plate and cover (W/m^2 °C)
h_{rp-c}	radiation coefficient between plate and cover (W/m^2 °C)
h_{rc-a}	radiation coefficient between cover and air (W/m^2 °C)
F_R	collector flow factor dimensionless
β	collector slope degree
$(\tau\alpha)_b$	beam absorptance-transmittance product unit less
$(\tau\alpha)_d$	diffuse absorptance-transmittance product unit less
θ	angle of incidence degree
θ_z	Zenith angle degree
S	absorbed radiation per unit area of collector (MJ/m^2)
U_t	overall loss coefficient (W/m^2 °C)
Q	net energy which can be gain by collector (MJ)
Nu	Nusselt number
Ra	Rayleig number
V	volume of domestic hot water (l)

sectors. Iran ranked the first NG producer, consumer and carbon provider among the Middle East countries in 2011 [2]. Consequently, the biggest environmental issue that Iran currently faces is air pollution owing to carbon emission. However, in 2011 total emissions from the combustion of NG in this country reached to approximately 334 million metric tons of carbon meanwhile it was almost 230 million metric tons in 2005 [2]. Tables 1 and 2 depict CO_2 emission from the flaring of NG among some developed and Middle East countries between 2005 until 2011, respectively. As it can be seen, Iran has third rank after two huge countries, U.S. and Russia, and the first in the Middle East in this issue. Moreover, Graphs 1 and 2 show the rising trend of Iran's CO_2 emission between 2005 until 2011 either globally or in the Middle East [2]. The share of Iran in this subject is 3 and 20% in the Middle East and worldwide, respectively [2]. Total NG consumption has reached from 105 to approximate 153.34 billion cubic meters between 2005 until 2011 [2]. Whilst, Saudi Arabia as a well-known hydrocarbon consumer has reached from 72 to 100 billion cubic meters among same years and has the second place [2]. Table 3 also lists NG consumption in the Middle East from 2005 until 2011 [2]. Additionally, Graph 3 shows Iran's rising trend of NG consumption from 2005 until 2011 and makes comparison between some major countries [2].

These statistics prove Iran has experienced rising trend either in NG consumption or in carbon emission in these recent years. Yet, the consequence of this heavy dependence on hydrocarbon fuels is becoming increasingly concerning. Several renewable resources – based on their feasibility – can provide supplementary sources for partially substituting fossil fuels. Currently, renewable energy contributes to about 11% of the world primary energy and this is expected to increase to 60% by 2070 [3]. Even in the Middle East countries, as the world's heart of the hydrocarbon resources, it is estimated that the renewable proportion in electricity production will reach 16% in year 2035 from 1% in year 2008 [3]. However, due to notable climatic diversity, Iran enjoys rich renewable natural resources including wind, solar and tidal waves. The

Table 1
CO_2 emission from the flaring of natural gas (million metric tons) [2].

Year	2005	2006	2007	2008	2009	2010	2011
China	92.08	110.95	138.59	151.70	173.94	209.74	257.33
France	99.81	102.12	94.99	99.59	95.26	97.20	99.33
Germany	184.32	186.86	180.87	184.92	176.60	175.16	151.60
India	71.85	77.13	82.17	85.17	105.60	127.33	126.32
Iran	229.75	244.16	252.48	266.90	308.92	316.51	333.97
Italy	165.35	161.94	162.73	162.70	149.56	159.28	149.35
Russia	806.77	856.56	859.04	881.91	769.90	845.63	1009.73
Turkey	53.30	60.77	71.19	71.00	67.64	73.44	86.13
United Kingdom	194.31	184.93	184.60	190.55	178.35	190.43	161.37
United States	1189.60	1174.79	1251.13	1262.04	1239.28	1299.74	1317.63
World	5677.85	5829.30	6011.63	6220.89	5985.53	6420.43	6754.72

Table 2
CO_2 emissions from the consumption and flaring of natural gas in the middle east between 2005 until 2011(million metric tons)[2].

Year	2005	2006	2007	2008	2009	2010	2011
Middle East	593.58	623.54	644.14	699.20	746.61	790.19	851.51
Bahrain	20.47	21.65	22.51	23.72	23.85	24.41	24.12
Iran	229.75	244.16	252.48	266.90	308.92	316.51	333.97
Iraq	16.78	17.10	15.56	14.24	14.58	15.91	18.73
Jordan	3.06	4.41	5.10	5.75	6.02	5.38	2.03
Kuwait	25.28	25.31	23.49	24.63	22.16	24.51	27.56
Oman	19.28	23.12	23.28	28.33	30.71	35.89	35.15
Qatar	46.46	46.81	47.19	49.00	51.58	50.79	46.06
Saudi Arabia	136.51	140.52	142.58	153.73	149.93	167.53	189.65
Syria	12.06	12.29	11.64	11.72	14.33	18.52	15.82
United Arab Emirates	82.51	86.26	98.08	118.39	116.72	120.53	149.71