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DESIGNING ZERO NET ENERGY RESIDENTIAL BUILDINGS BY SOLAR ENERGY IN IRANIAN CLIMATE ZONES

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ABSTRACT

The purpose of this paper is to assess the energy consumption per area unit of a residential building by using solar energy in different Iranian climates, which is able to act as zero net energy in minimum area under structure. In order to achieve this target (due to the lack of reliable solar insolation map for Iran), first of all Iran approximated solar insolation map was extracted by using Angstrom-Pryskat method in terms of receiving solar energy and then the different Iranian climates were studied. Residential building designing was commenced through concluding the said two factors in 12 different locations throughout Iran in terms of the potential of receiving solar energy and different climates, as zero net energy by using solar energy, while eventually an average energy consumption of 75.41 kWh/yearm2 from 12 different Iranian locations, which on average uses 35.2% of this energy directly and the balance (64.8%) is used indirectly from the network and in the form of Grid-connected photovoltaic system (Net-metering system). Meanwhile, the primary cost of these buildings design was achieved as 352 USD/m2 with a capital return term of 10.2 years.

Keywords: Zero Net Energy Residential Building; Solar Energy; Iranian Weather Climate Zones; Iranian Radiation Climate Zones.

I. INTRODUCTION

The idea of zero energy buildings as a mean to decrease carbon contamination and dependency on fossil fuels has been considered, while the projects related to the same are quite practical considering the increased fossil fuels costs and their destructive effects on environment, climate conditions and involvement in ecologic balance [1]. Whereas one of the major targets of electrical power industry in Iran is increasing the generation capacity of solar power plants prioritized towards domestic power, and as for the time being the power company purchases the solar power generated in houses for a price 6.5 times the selling price from the residents, the focus of this paper is on zero net energy residential buildings using solar energy.

Considering the high potential of receiving solar energy in most regions of Iran, heating, cooling and even selling excessive solar energy to power company are possible by using this energy in buildings to absorb heat in different parts such as photovoltaic panels, thermal and photovoltaic collectors, etc. and the idea of zero net energy in Iranian buildings enjoys implementation potential.

It should be noted that Iran's Geographical Location and natural physical characteristics import a wide climatic diversity to the country. There is a difference of 15 deg. latitude between the Northernmost and Southernmost urban centers of the country and a difference of 2500 M. in the altitude between the lowest and highest residential areas, etc. have resulted in a quite variable climatic conditions in different regions while such climate variability requires predicting a certain form of residential buildings to maximize utilization of solar energy and in proportion to each of the different climatic zones [2].

II. METHODOLOGY

The most cost-effective stages in terms of expenditures to decrease energy consumption in a zero net energy building occur during the design process [3] (figure 1). The general algorithm used to design a zero net energy building has been given in figure 2, while the same algorithm has been applied to design the buildings of this project with certain changes (figure 3).

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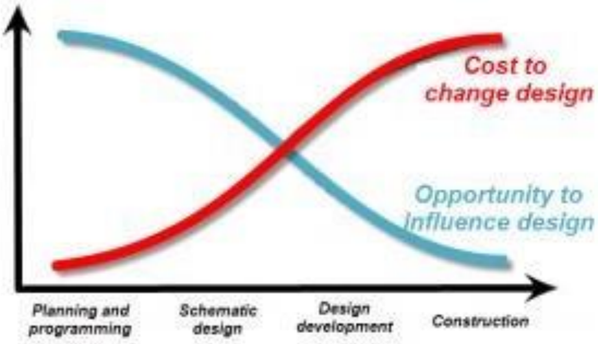

Figure 1: Relation between cost to change and opportunity to influence design in a zero net energy building during the time [3]

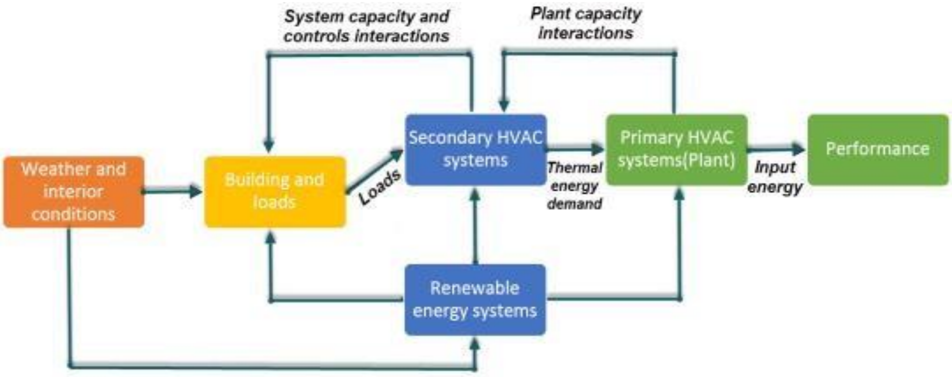

Figure 2: The general algorithm used to design a zero net energy building [3]

Due to inaccessibility to advanced software to fulfill algorithm of figure 2 automatically and in an optimized manner, the algorithm shown in figure 3 was used in this project to design a zero net energy residential building by using solar energy in 10 stages manually, while in turn is an innovation in designing a zero net energy building without optimization software. However, it should be noted that in order to decrease Vilfredo Pareto front of the relevant multi-objective optimization issue, certain defaults have been applied in each stage and also the stages marked with a red star (*) at the top in figure 3 remain unchanged in the cycles of this algorithms to achieved the desirable level of a zero net energy building, i.e., the amount of annual energy provided by on- site renewable energy sources are equal to the amount of annual energy used by the building.

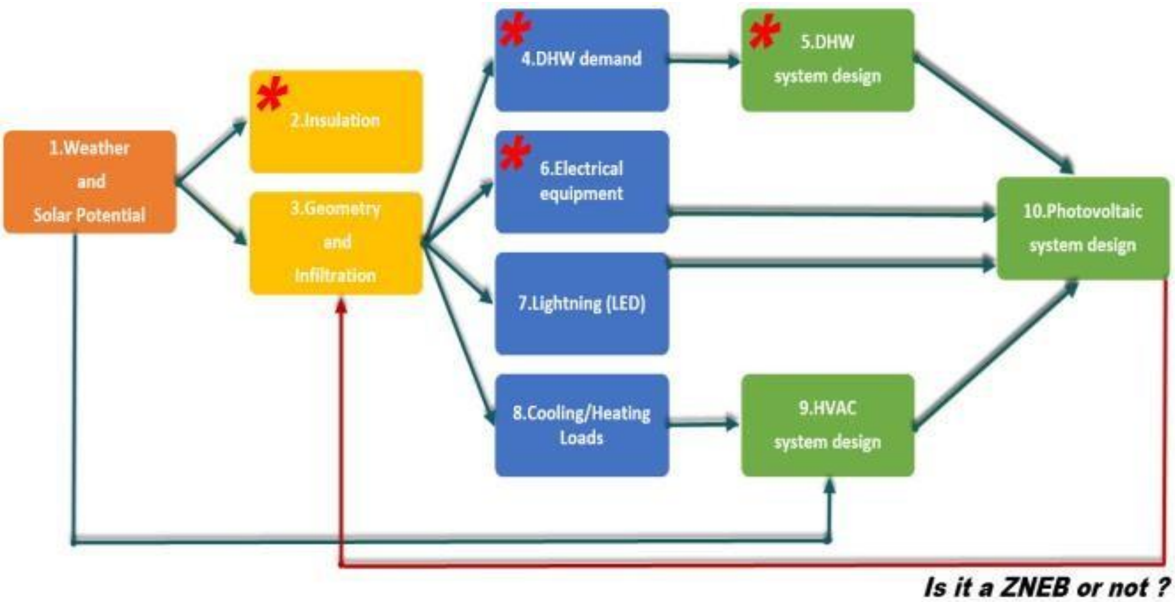

Figure 3: The algorithm used to design zero net energy buildings

III. MODELING AND ANALYSIS

Through determining structural and geometrical parameters of the building in Carrier's Hourly Analysis Program (HAP) software [4], the annual cooling and heating loads required for buildings were found in 4 radiation and 8 weather climates in 12 different cities. In order to design the domestic hot water system, TSOL software [5] has been used (figure 4), while PVSOL software [6] (figure 5) has been applied for designing a suitable photovoltaic system to supply electrical requirements of cooling, heating and miscellaneous appliances.

Figure 4: Domestic hot water system of the sample buildings designed by TSOL software

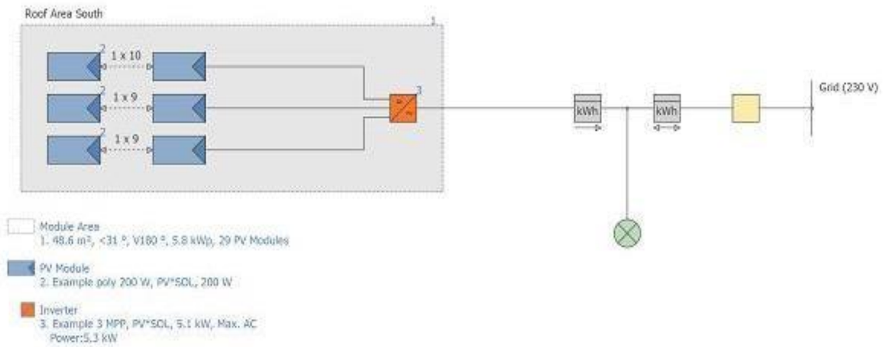

Figure 5: Photovoltaic system electrical circuit of the sample building designed in Tehran city by PVSOL software

Based on figure 3 algorithm, first of all 8 Iranian weather climatic zones were studied (figure 6) by using "Climatic Classification of Iran for Housing and Urban Design" [2] book, then an approximate solar insolation map has been drawn for Iran based on Angstrom-Pryskat method [6] (figure 7). Through placing these two maps besides each other and overlapping the same, 12 cities have been determined to design zero net energy buildings (figure 8).

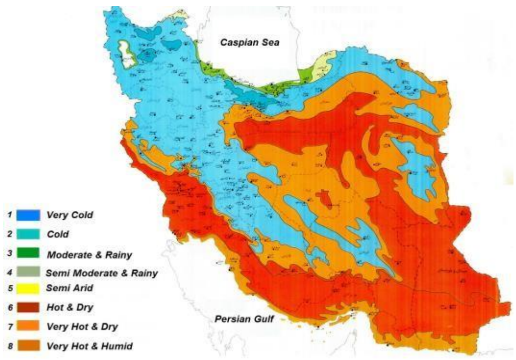

Figure 6: Climatic zones map of Iran [1]

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Figure 7: Approximate solar insolation map of Iran

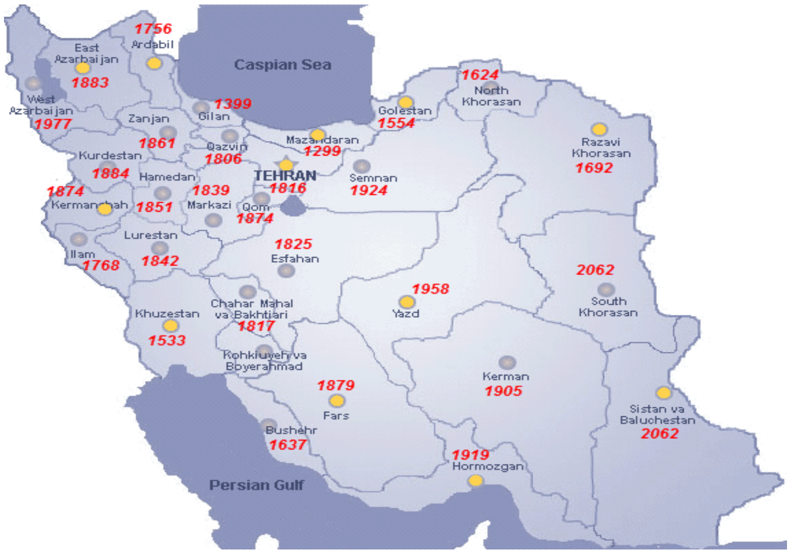

Figure 8: Solar potential (kWh/yearm2) and location of 12 cities have been determined to design zero net energy buildings

In the second stage of the algorithm presented in figure 3, the R-value associated to insulation in each of the 8 climates for a zero net energy building have been compared with different Iranian climates [7] by taking benefit from climatic standard determined for a building with low energy consumption (figure 9).

Table 1. R-value associated to insulation for a zero net energy building in each of the 8 Iranian climate zones

Weather climatic zones No.						R-Value ($\frac{hr ft^2 °F}{btu}$)
8,7	6	5	4	3	1,2	Insulation
22	22	22	25	22	30	External Wall
38	38	38	38	38	40	Ceiling
22	19	19	22	19	22	Attic
22	20	20	25	20	30	Floor(Area)
11	11	11	13	11	15	Floor(Exposure)
5	4	3	4	4	5	Door-Window

In the third stage of the algorithm given in figure 3, after identification the angles and geometrical aspects of building in Carrier's HAP software with the purpose of absorbing maximum solar energy, the infiltration was chosen between 0.3 and 0.5 Air Changes per Hour (ACH) based on American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 62-2001, in the 4th and 5th stages the domestic hot water consumption is determined and the relevant system proportion to the same is designed.

After determining consumable power of home appliances and lighting systems, maximum cooling load of the hottest day of the year and maximum heating load of coldest day of the year are calculated in the eighth stage and then by using two concepts of cooling degree days (CDD) and heating degree days (HDD) (figures9),

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building annual cooling and heating loads, are achieved, respectively, while by using two seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF) concepts of super-efficient cooling and heating systems, their annual consumable power is calculated. After calculation of the total annual consumable electrical energy, 4 sectors of lighting with Light-emitting diodes (LED), home electrical appliances, heating-cooling system and consumable hot water supply system, in the ninth and tenth stages photovoltaic system electrical circuit together with 3D simulation has been designed and the annual results of this system have been calculated. Eventually, the repetition loop of this algorithm continues until the building annual generated renewable energy equals to its annual consumable energy of the same, which is the purpose of a zero net energy building.

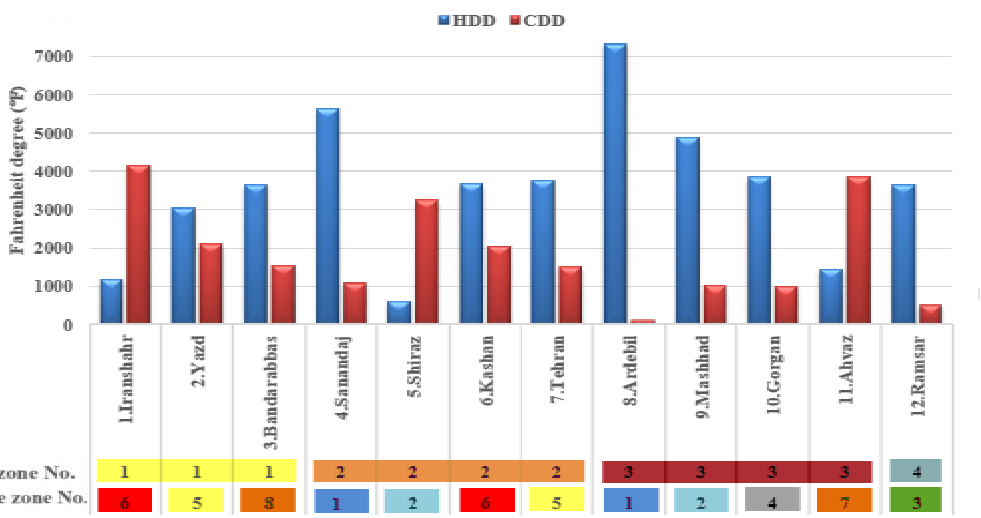

Figure 9: Average (during the past three years) annual CDD and HDD of 12 cities have been determined to design zero net energy buildings

IV. RESULTS AND DISCUSSION

In case we focus the building designed in Tehran, we observe that Tehran is situated in radiation region No. 2 and climate region No. 5 of Iran and the average potential to receive solar energy of the same is 1816 kWh/yearm2. The annual cooling and heating peak loads of this building is given in figure 10 and considering the fact that average HDD and CDD in Tehran during the past three years have been 3,778 and 1,511, respectively, and SEER- HSPF of its super-efficient cooling and heating systems selected is equal to 21.3 and 9.6 (Due to the average temperature for the year in Tehran is 17.8°C), respectively, their annual consumable power is calculated accordingly. Meanwhile, the annual results of domestic hot water system of the building designed in Tehran city sample building have been shown together with heat losses of different sectors in figures 10 thru 12, respectively.

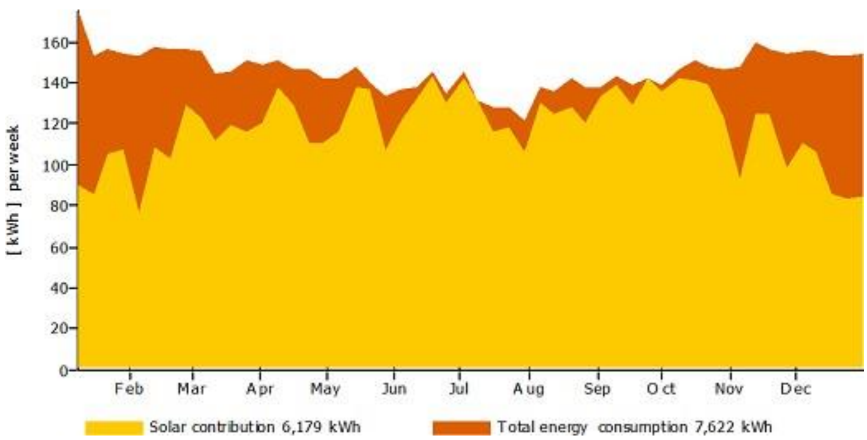

Figure 10: The annual results for solar energy consumption as percentage of total consumption of domestic hot water system designed in Tehran city sample building

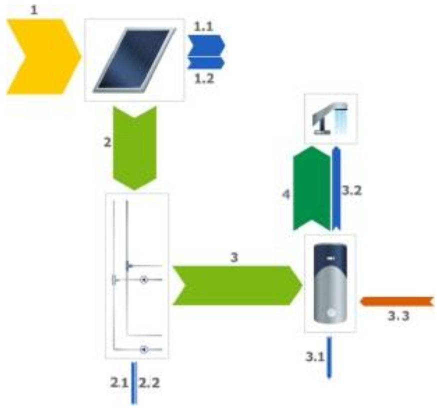

Figure 11: Schematic of figure 12 and figure 3 for domestic hot water system designed in Tehran city sample building

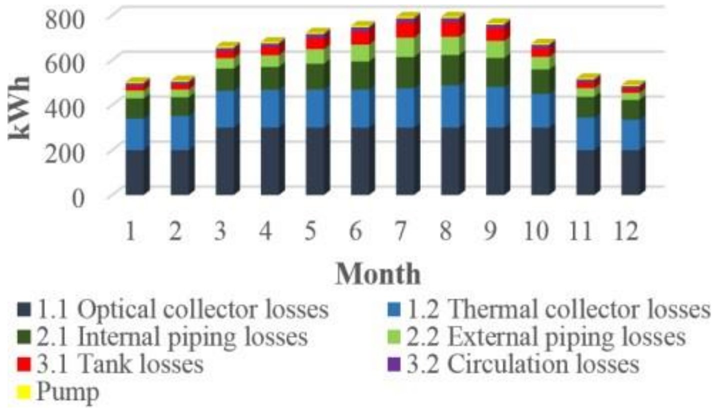

Figure 12: Heat losses for different parts of domestic hot water system designed in Tehran city sample building

The total annual consumable electrical power of 4 sectors of lighting (with LED), home electrical appliances, cooling- heating system and domestic hot water supply system (figure 13) of this two-floor residential building with roof slope angle of S 31.6 (figure 14) for a 5-member family is an area of 120 square meter (each stage 60 m2) with the total annual energy of 9260 kWh, of which 35.1% is consumed directly and the balance (64.9%) is transmitted to the city power system and consume the same when necessary (figure 15).

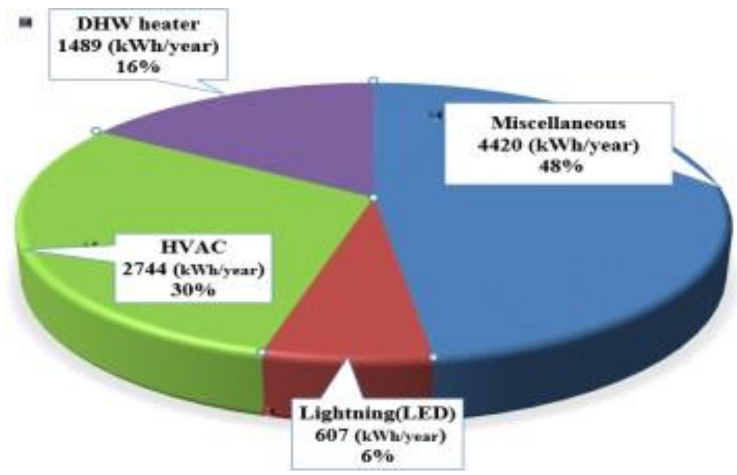

Figure 13: The total annual consumable electrical power for designed Tehran city sample building

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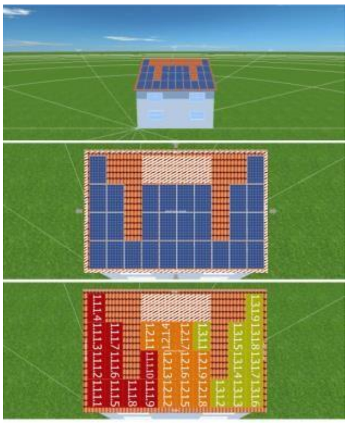

Figure 14: South view of designed Tehran city sample building and its 3D photovoltaic systems in PVSOL software

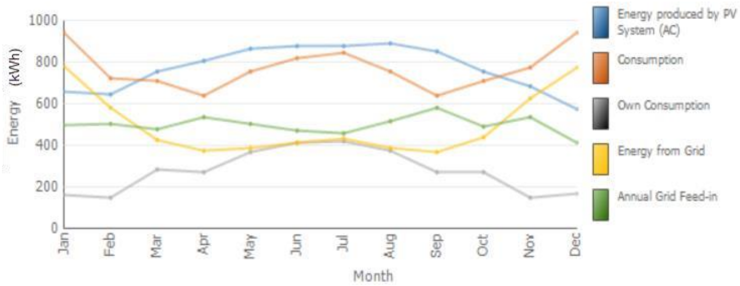

Figure 15: photovoltaic system annual energy balance of the sample building designed in Tehran city

Meanwhile, photovoltaic system electrical circuit of the building designed in Tehran city sample building with heat losses of different sections of the same system have been shown in figure 5 and 16, respectively.

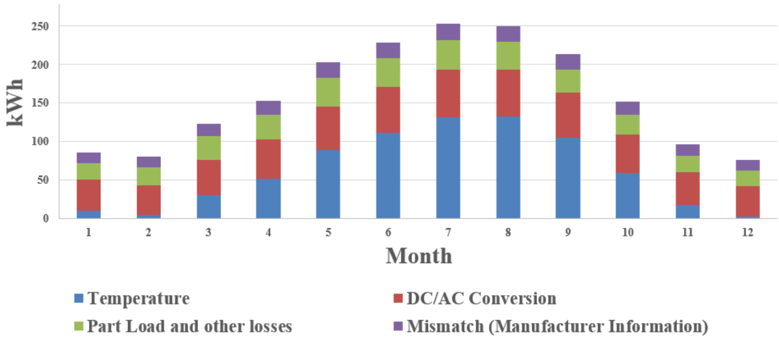

Figure 16: Heat losses for different sections of photovoltaic system of the sample building designed in Tehran city

The total costs of 4 sectors: insulation, LED, HVAC systems and solar systems of the building designed in Tehran city will be equal to USD 40,000, of which 50% is granted by Iranian government as loan and it has a capital return chart as figure 17 considering the fact that +20% inflation rate in price of selling/purchasing electrical energy(during the past three years) and selling price of electrical energy to residents is equal to USD/kWh 0.05 and the power company purchases electrical power with a fixed price of 0.32 USD/kWh from the residents of these buildings.

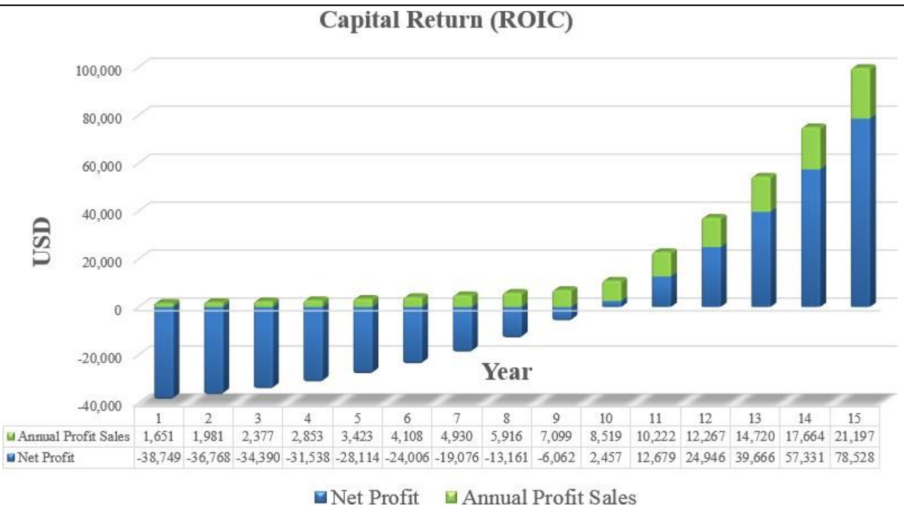

Figure 17: Capital return chart of the sample building designed in Tehran city

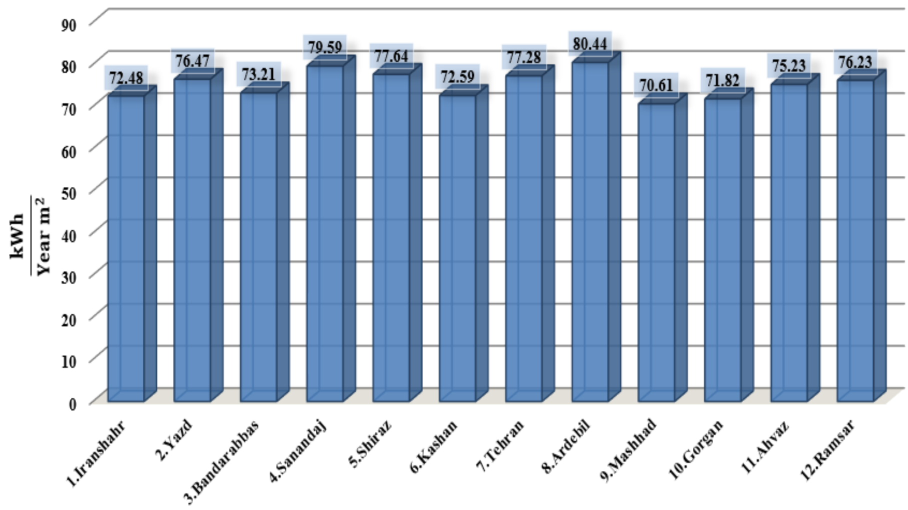

Figure 18: Energy consumption per area unit of 12 Iran cities

V. CONCLUSION

Results of this project from 4 radiation regions and 8 climate regions of Iran (figure 18) indicate that considering the high solar energy potential in Iran, the idea of zero net energy building is totally viable theoretically and it is almost the same (between 70-80 kWh/yearm2) for 12 cities have been determined to design zero net energy residential building in this project, and by taking benefit from governmental finance for residential solar energy sector and continuous increased efficiency of solar systems, in addition to the theoretical considerations it is a project which is potentially feasible throughout the country. Results of the energy consumption per area unit of 12 cities have been determined to design zero net energy residential building by using solar energy in 4 radiation regions and 8 climate regions of Iran in Fig. 18.

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