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Construction and Analysis of Smart Solar Bench with the Optimal Angle in Four Central Cities of Iran

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Abstract

Since Iran has an average of 256 sunny days a year, solar energy in Iran can be used on a large scale. There are many mathematical models for measuring radiation on the surface, but choosing the best model can help measurement accuracy. In this article, first, direct and diffused radiation in Shiraz, Isfahan, Kerman, and Yazd, which are the central cities of Iran, has been calculated. The calculation has been done using the NRI model in MATLAB software. The powers received from this bench are computed in each city and their maximum efficiency is shown. The mentioned solar bench was built with a fixed angle. By comparing the efficiency between the mentioned cities, we identified the city with the most suitable place for building this solar bench. In Kerman, we can receive the highest amount of power throughout the year by using the optimum angle which measured. Due to the location of this city, it was expected to have the highest amount. This article examines the technical methods of using solar systems in urban architecture, emphasizing integration methods. The proposed and implemented model of the solar tree has the options to adjust the optimal angle and beautify passages, parks, and recreation centers. All these features make it useful to charge electronic equipment such as mobile phones, tablets, and electric bicycles through clean solar energy.

Keywords: Solar Energy; Solar bench; Street furniture; NRI Model

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1. Introduction

Energy generation is considered a significant challenge through industrial evolution, especially as the global population is exponentially increasing [1]. The two significant challenges of environmental pollution and the limitation of fossil energy resources in the world have made energy one of the most significant crises of the 21st century. Restrictions on non-renewable resources have led researchers to study the use of pure and renewable energy [2]. Given the increase in population and uncontrolled consumption without saving, this great blessing will undoubtedly end in the not too distant future. Perhaps in the meantime, some countries are somewhat safe due to their abundant fossil fuel resources. Using suitable consumption methods, optimizing energy consumption, and using renewable energy can control and curb the energy challenge [3]. Renewable energy sources continue to be developed as an alternative energy source to

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substitute for depleting fossil energy [4]. One of them is a power plant with solar cells that use solar energy heat sources [5, 6]. Fossil fuels and conventional energy generation processes have dominated the energy supply, with coal, crude oil, and natural gas representing more than 80% of the primary energy supply in 2018 [7]. The use of PLN electricity is still a lot of seethes than if the electricity supply from PLN is cut off, there is no alternative source to replace. So it becomes a condition that causes an energy crisis [8].

Energy problems that hit the world have implications for savings in all fields [9]. Solar energy is of great importance among renewable energies due to less environmental pollution, free, easier access, and more [10]. Renewable energy sources continue to be developed as an alternative energy source instead of depleting fossil energy [11]. Communities are expanding and migrating into formerly uninhabited spaces and developing technologies, hence increasing the energy demand in general, and the electrical energy load in particular [12]. A secure, environmentally friendly, and efficient energy source is needed now more than ever for a sustainable and healthy society [13].

In recent years, there have been many studies on the use of solar energy, most of these studies have been done to increase the efficiency of previously made models, but in some cases, new and innovative technologies are seen as a good step towards the use and utilization of solar energy [14]. Presently, the world energy consumption is 10 terawatts (TW) per year, and by 2050, it is projected to be about 30 TW. The world will need about 20 TW of non-CO2 energy to stabilize CO2 in the atmosphere by mid-century. The simplest scenario to stabilize CO2 by mid-century is one in which photovoltaics (PV) and other renewables are used for electricity (10 TW), hydrogen for transportation (10 TW), and fossil fuels for residential and industrial heating (10 TW) Thus, PV will play a significant role in meeting the world future energy demand. The present is considered as the “tipping point” for PV [15]. IRENA's statistics report of 2019 has reported that renewable energies, in general, have seen a 7.4% growth in capacity with a net capacity increase of 176 GW in 2019, out of which 54% being installed in Asia alone, with 90% of it being new capacities of solar and wind energies. Renewable energies are dominating the new power installation reaching about 70% in 2019 [16, 17].

In this decade, the cost of installing and managing photovoltaic systems has been greatly reduced. One of the implementations of solar cells (Photovoltaic) is electricity in public open spaces that require electricity [18]. Solar energy has the potential to expand into large-scale operations and fulfill industrial and domestic use. Research has chosen few best business opportunities and ideas for the rural people who are willing to start their business with solar products. A solar panel or solar business is one of the most profitable businesses today. Solar energy business profitability is at the top position at present and will stay there in the future. Consequently, different entrepreneurs have realized the need of the moment and are starting their solar energy business ventures [19]. The business potentials are product selling, inventing solar products, developing & own solar projects, independent solar consultants, solar repairs, sell aftermarket products [20].

GIS is a powerful tool for analyzing data, maps, and spatial information which has been used to study the optimal location for the construction of a solar power plant in recent years. Concerning Iran, as the results of the present work in Figure. 1. also suggest, it is reported that provinces in the Southern half of the country have the adequate potential for using solar energy. Having 280 sunny days per year in more than 90% of the country's areas, much research is conducted on solar energy in Iran. It is reported that solar energy is the most available and cleanest type of energy in Iran. However, being rich in oil and gas resources and the availability of cheap national grid power, solar energy is not used to its full potential in Iran [21].

Today, various methods have been used to extract solar energy. Researchers are also looking for ways to make the most of solar energy, given that the earth plays an essential role in all matters, including industry, agriculture, and construction. In addition to proper use of the sun, the proper use of the occupied land area must also be considered [22]. One implementation of solar cells (Photovoltaic) is a source of electricity in public open space facilities that require electrical energy [18].

This research proposes new solutions for alternative sources of electrical energy in open spaces by implementing a solar panel in a bench object. This paper calculates the potential of four cities (Shiraz, Isfahan, Kerman, and Yazd) to receive electrical power from a panel. In Iran, areas with the most potential were chosen with at least 1700 kWh/m2/year and 1350 kWh/m2/year annual average solar radiation for photovoltaics (PV) and concentrated solar power (CSP), respectively [23]. Next, the NRI radiometric model and an algorithm for calculating the optimal slope are introduced in the material and method part. Then, direct and scattered radiation is calculated, and the details of the output power calculations are placed according to the pattern defined in this section. The bench made in the results section is introduced, and the maximum power extractable from this bench in 4 cities Is calculated and compared. The specifications of the panel used are given in Table 1.

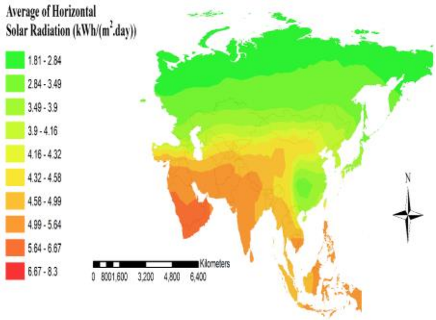

Figure 1. Average radiation on a horizontal surface for Asian countries [21]

1.1. literature review

First Montenegrin solar bench has been designed and produced in Podgorica, Montenegro, in 2018, by Bojovic M. [24]. It is sophisticated, self-sustainable smart solution and presents new generation of urban furniture. The basic model of the bench provides remote access to USB ports for charging mobile devices and Wi-Fi infrastructure for hotspot implementation in an urban setting. Green energy is harvested via solar panel, integrated into the seating area. This smart piece is implemented in urban settings as well as in the city parks, avoiding partial shading if possible [25]. The first version of the bench is made in painted steel and plexiglass.

In the last few years several start-ups started offering new smart urban furniture. They employed the IoT technology to create small urban furniture able to provide different services. Some examples are the US start-up and MIT spin-off “Changing Environments Inc.” which produced Soofa Bench and Soofa Sign, [26]. These are simple benches made of steel and timber with a solar panel installed in the middle. The solar panel, in this case, is not part of the bench as the people cannot sit on top of it. The design is functional but basic and the visibility of the PV panel is high due to its position.

The installation of the new solar street furniture on KAUST campus in Saudi Arabia has been completed in 2020. This is a circular outdoor seating, incorporating flexible, lightweight and transparent solar technologies developed by King Abdullah University of Science and Technology (KAUST) Solar Center. The seating is shaped as a circular object where PV panels are placed on the external curved surfaces. These modules are constituted by organic photovoltaics (OPV) and they are semi-transparent. Due to its shape the object is highly visible in an urban context. However, the integration of PVs with the form of the bench is achieved through the flexibility of the adopted cells which also merge into the design [27].

Aromal V, et al. [28], in one study deals used PV array and the converter circuit to use the output power of the PV array to charge the battery of the solar assisted electric wheelchair. P&O algorithm is used to track the maximum power point which enhances the efficiency of the panel. The mechanical arrangement that holds the solar panel on top of the wheelchair setup ensures that the panel is subjected to maximum irradiance and it works at maximum efficiency. The position of the panel can be adjusted manually by using a switch and a power window motor. It also ensures that the person is protected from exposure to harmful rays of the sun. Elejoste P. et al. [29] has resulted in a bench prototype that has a power supply using a solar cell. The bench is designed to have an LED light facility designed to automatically turn on based on the intensity of the surrounding light. Another feature is that the bench has a mobile phone charging station. E. Duque, et al. [30], considers the design of a solar tree photovoltaic system to load mobile devices in open urban areas, a proposal proposed by the Faculty of Engineering of the Pascual Bravo University Institution, in the city of Medellín. Recently, street furniture, including bins, seats, and bus shelters, has become smart as it has been equipped with environmental sensors, wireless modules, processors, and microcontrollers [31].

Solar tracking systems are used to increase the amount of electric power generated from solar panels. Tracking devices are of two types – dual axis and single axis. The tracking mechanism of the *single axis* tracker involves the movement of the panel in only one axis. This is either horizontal when it is observed that the sun is much at noon or the vertical axis which is mainly used in period of average sun intensity and long summer. A Single-Axis Solar Tracking System and Monitoring Software have been reviewed [32, 33], and also conducted [34-37] with the aim of increasing energy generation of the photovoltaic (PV) panels. Zarei Zohdi H, et al. [38], a 20 kW power plant connected to the grid in Tehran was designed using PVsyst software. The performance of the solar power plant was evaluated when the panels were without a tracking system (fixed) and when the system used a two-axis tracker. It was also shown that the energy generated in a year using a two-axis tracking system increased by 37.87%.

Adibpour S. [39] a pseudo two-axis sun tracker is presented and applied for installing the photovoltaic panel on. In this tracking system, one rotating motor is used instead of two, and more solar radiation is absorbed compared with common one-axis tracking systems. The results show that pseudo two-axis sun tracking system gains 2.82% more radiation than the conventional one-axis sun tracker. Through adjusting the angle two times a year, 4.01% more radiation is gained and adjusting the angle four times a year results in gaining 4.12% more radiation, while using a two-axis sun tracker results in 4.39% more radiation on the panel compared with one-axis sun tracker. The pseudo two-axis sun tracker's performance with adjusting angle four times a year has little difference with two-axis sun tracker and due to using one motor instead of two, using a pseudo two-axis sun tracker is more economical. The percentage of increased radiation of pseudo two-axis sun tracker compared with fixed panel differs for various cities, which could be as high as 31% for some major Iranian cities. Chin et al. [40] designed, modeled, and tested an active single-axis solar tracker. The computer model of the stand-alone solar tracker system was modeled using MATLAB/Simulink, which was in accordance with the experimental model. The results of the study revealed that the efficiency of the smart tracking panel was approximately 20% more than that of the fixed panel. Colli and Zaaiman [41] tested three solar panels using different forms of crystalline silicon in Italy. They proposed a methodology based on the effective maximum power of the PV modules which was applied to the fixed and one-axis sun tracking systems. The study showed that PV modules installed on the single-axis tracker had better performance than the fixed PV module. The total monthly irradiance gained by one-axis tracker was 19% and 23% more than the irradiance on fixed module for March and April, respectively. Eke et al. [42] have analysed performance results of double-axis sun tracking photovoltaic systems after one year of operation. Two identical 7.9 kWp PV systems with similar modules and inverters were installed and tested at Mugla University. Results showed that 30.79% more PV electricity was obtained in the double-axis sun tracking system when compared with the fixed system. In another piece of research, Jafarkazemi et al. [43] found the optimum tilt angle for south facing flat-plate solar collectors in Abu Dhabi. A mathematical model was used for estimating solar radiation at different tilt angles. Based upon the study results, it was recommended to adjust tilt angles at least twice a year. Optimum tilt angles for cloudy sky cities with a low clearness index were lower than those for cities at the same latitude angle having a higher clearness index. It was found that in addition to latitude angle, the climate conditions were also important for determining the optimum tilt angle. Ingenhoven et al. [44] compared the obtained energy in one-axis and two-axis tracker panels and fixed panel. The study was conducted in the Italian Alps. The findings showed that one-axis and two-axis sun tracking systems generated 22% and 25-26% more electricity in comparison with the fixed panels, respectively.

2. Methodology

2.1. Optimal angle

There are various mathematical models for measuring the sun's radiation on the panels' surface and measuring them to get their maximum extractable output. It should be noted that the difference between these mathematical models is only in the way of calculating scattered radiation; of course, the complexity of the calculations is what has caused the difference between the models. This paper uses the NRI model to estimate the solar energy potential.

2.2. NRI model

In this model, the solar radiant energy is calculated based on the sun's altitude angle, the cloud factor and the inclination angle. The amounts of direct and scattered sunlight on a fixed panel are computed from the Equations (1,2) [45].

$$I_{b,n} = F_b(\delta)[(1-\exp(-\frac{0}{075}\alpha)] \tag{1}$$

$$I_{d,h} = F_d(\delta)[0.123+0.181\alpha+10.43CF] \tag{2}$$

Table 1. The specifications of the panel that used in this bench

Monocrystalline	Material
30 V	Maximum power point voltage
8.34 A	Maximum power point current
37.5 V	Open circuit voltage
8.8 A	Short circuit current

$I_{b,n}$ refers to the intensity of direct radiation on a vertical plane and $I_{d.h}$ scattered radiation on a horizontal plane. Also, α is the angle of elevation and in terms of degree, C.F. is the cloud factor, and δ is the angle of inclination. Also the declination effectiveness coefficients, F_b and F_d are calculated in Equations (3-8) [46].

$$F_b(\delta) = C_{b1}\delta + C_{b2} \tag{3}$$

$$F_d(\delta) = C_{d1}\delta + C_{d2} \tag{4}$$

$$C_{b1} = -\frac{563}{8} \times 10^{-5} (KW / M^2 / \deg) \tag{5}$$

$$C_{b2} = \frac{0}{9876(KW / M^2)} \tag{6}$$

$$C_{d1} = -6.9 \times 10^{-5} (KW / M^2 / \deg) \tag{7}$$

$$C_{d1} = 0.0121(KW / M^2) \tag{8}$$

Sunlight reaches the earth's surface regardless of weather conditions, but its intensity decreases as it passes through the clouds. This type of radiation is called scattered radiation, impacting the calculation of scattered radiation on cloudy and foggy days. Scattered irradiation is shown in Figure. 2. It should be noted that direct radiation is much stronger because sunlight reaches the earth's surface without being blocked by clouds.

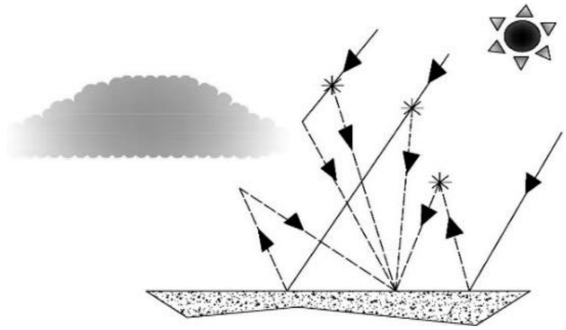

Figure 2. Scattered irradiation

The total radiation received by the desired page can be written in Equation (9) [46].

$$I_{t,a} = I_{b,a} + I_{d,a} \tag{9}$$

$I_{b,a}$ represents direct radiation, and $I_{d.a}$ represents the screen's scattered radiation. I_{ba} and I_{da} are calculated by Equations (10,11) [46].

$$I_{b,a} = I_{b,n} \cos\theta_i \tag{10}$$

$$I_{d,a} = I_{d,h}\left(\frac{1+\cos\beta_i}{2}\right) + \rho_{alb}\left(\frac{1-\cos\beta_i}{2}\right) \tag{11}$$

Where θ_i is the angle of impact (angle of solar radiation with the average plane vector) β_i is the slope of the plane relative to the horizon, ρ_{alb} is the reflection coefficient of the earth's surface and $I_{t.h}$ is the intensity of the total radiation on a horizontal plane that calculated by Equation (12) [46].

$$I = I_{b,n}\cos(90-\alpha) + I_{d,h} \tag{12}$$

The angle of collision θ_i for any plane with an angle of deviation β from the horizon and an angle of inclination γ concerning the north axis can be calculated in terms of the angle of inclination of the sun δ and the angle of incidence ω and latitude φ at any time [46]. For a fixed plane, the angle of incidence is obtained according to Equation (13) [46].

$$\begin{aligned}\cos\theta i &= \cos\beta(\sin\delta\sin\varphi + \cos\delta\cos\varphi\cos\omega) \\ &- \cos\delta\sin\omega\sin\beta\sin\gamma + \sin\beta\cos\gamma(\sin\delta\cos\varphi \\ &- \cos\delta\cos\omega\sin\varphi)\end{aligned} \tag{13}$$

In this case, $\beta_i = \beta$. In Figure. 3., the angles ϕ_C are called the azimuth angle, which is the panel's angle with a negative value in the southwest. The angle ϕ_S is called the sun's elevation angle and represents the angle of the image of the sun's rays with the south, and Σ is the angle of the panel with the horizon.

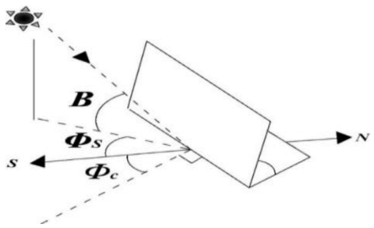

Figure 3. Φc: panel angle with south, ΦS: sun angle image with south and Σ: panel angle with the horizon.

The electrical energy generated by the photovoltaic cell is calculated by Equation (14) [46].

$$E = \frac{1}{n_f - n_s + 1} \sum_{n=n_s}^{n_f} \left[\int_{sunrise}^{sunset} I_{t.a} d_t \right]_n \quad (14)$$

Where n, n_s, and n_f are the number of the desired day, the beginning and the end of the time interval, respectively, and the time of integration of sunrise and sunset is each day. The above formula shows that the integration interval values differ for each day. Still, the value in these calculations is considered from 7:30 to 16:30 according to the shortest day of the year (December 21). Therefore, the values obtained will increase significantly, especially in summer.

2.3. Solution Algorithm

Figure 4 shows the flowchart for calculating the structure's optimal slope and maximum energy received. Accordingly, inputs generally fixed, such as the cloud factor, latitude, and panel angle, typically zero degrees, are entered to obtain the amount of radiation and energy that can be received at the horizon. Also, this angle is changed from zero to 180 degrees to the south at the other entrance. According to the formulas presented, the maximum monthly and annual radiation are calculated. Finding the best slope and calculating the utmost energy, in each step, 20 degrees is added to the panel angle, and by calculating the new direct and scattered radiation and entering the panel efficiency, which is a constant value of 20%, each time the energy from that degree it is compared with the energy obtained from the previous angle. When the nine steps of these changes are done, the maximum amount of energy is adjusted to its angle; On the other hand, in the equation for calculating efficiency, we need a diary, which, by applying it, obtains the best slope and maximum energy that can be received per month.

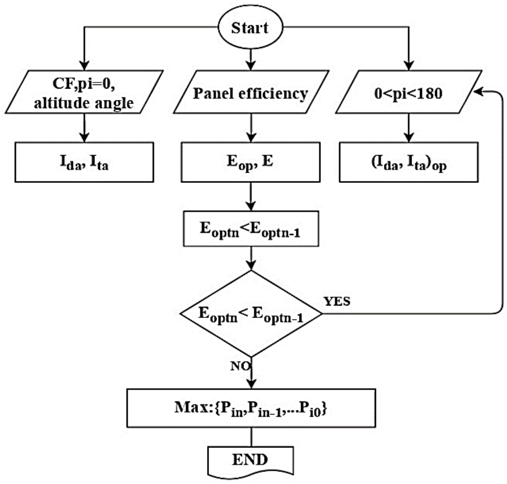

Figure 4. The flowchart of optimized slope and maximum received energy calculation process [47].

3. Results & Discussion

3.1. Optimal Angle

According to the description, the complete design of the solar bench can be seen in Figure. 5,6.

Figure 5. Solar bench

Figure 6. The panel that used in the solar bench

The amounts of monthly direct and scattered radiation are shown in Figures. 7,8. These values are obtained from equations (10,11).

According to the flowchart description in the previous section, nine samples are taken each month to find the maximum power. Table 2. shows these samples at every twenty degrees change for each month of the year. After finding the maximum power, it is adapted to the relevant angle. To find the optimal slope, twenty more samples are taken in the interval where the maximum power is received; thus, the optimal slope for each month is calculated. The result of these calculations can be seen in Table 3. These values are the panel's angle facing south, and the negative angle means the panel is sloped north.

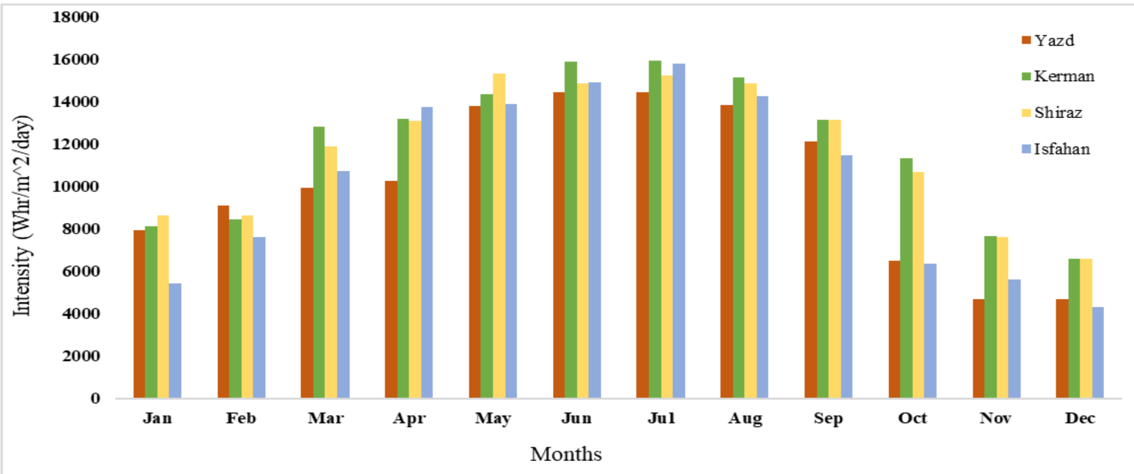

Figure 7. The direct irradiation in four mentioned cities

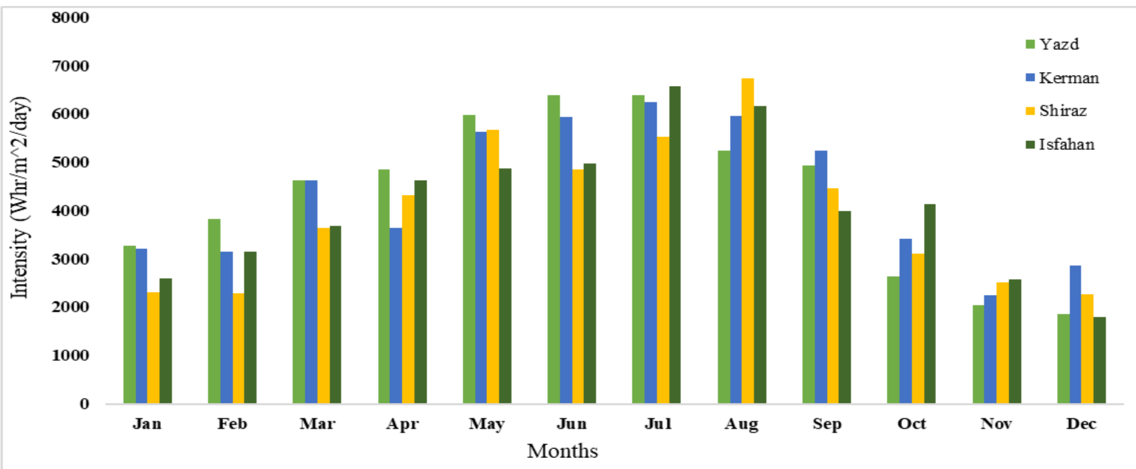

Figure 8. The diffused irradiation in Yazd, Kerman, Shiraz and Isfahan

Table 2. Samples of each month to find the maximum power

Cities	Angle (Degree)	Power per a month (Watt)											
		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Shiraz	0-20	21.8	20.2	27.2	**31**	**43**	**41.1**	43.7	**46.7**	36.9	**26.7**	17.3	16.8
	20-40	23.1	21.5	**28.0**	28.6	41.6	40.8	41.5	44.1	**37.1**	24.2	19.5	17.9
	40-60	**24.8**	**22.3**	26.1	26.9	40.5	39.1	40.1	44.9	35.2	22.7	**20.2**	**18.1**
	60-80	22.1	19.4	23.7	25.3	39.4	33.2	39.6	42.5	32.6	20.6	18.3	14.5
	80- (-80)	18.0	16.3	20.8	24.0	38.1	35.4	37.2	41.8	29.9	19.6	17.9	11.6
	(-80)-(-60)	18.6	17.2	22.9	25.8	39.5	36.4	38.4	42.9	30.6	20.9	18.4	12.7
	(-60)-(-40)	19.6	18.9	24.2	27.5	40.2	37.1	40.0	44.1	32.2	21.7	18.6	13.5
	(-40)-(-20)	20.8	19.2	26.8	28.1	41.9	39.2	43.6	44.5	34.3	24.8	17.7	14.1
	(-20)-0	21.7	20.1	27.3	30.8	42.7	41.0	**44.3**	45.3	36.0	26.1	17.6	16.4
Isfahan	0-20	18.2	20.3	25.1	35.6	**38.3**	**41.2**	**45.2**	**44.7**	28.2	21.4	21.9	15.9
	20-40	19.6	22.5	**27.3**	**36.2**	37.2	40.6	43.6	42.6	**29.1**	23.7	22.1	16.5
	40-60	**21.1**	**24.0**	26.2	34.8	35.9	35.2	40.9	39.8	25.4	**25.2**	**22.7**	**18.1**
	60-80	19.6	23.9	24.3	33.3	30.8	30.1	37.5	37.2	21.7	22.9	19.5	16.2
	80- (-80)	17.3	19.8	18.3	29.2	27.6	28.3	36.3	35.6	20.6	17.3	16.9	15.3
	(-80)-(-60)	18.1	19.9	20.8	30.2	28.4	32.9	37.9	36.9	21.9	18.6	17.4	13.8
	(-60)-(-40)	17.5	20.6	22.7	31.6	30.9	37.9	38.6	38.4	25.8	19.3	19.7	14.1
	(-40)-(-20)	18.9	21.6	23.5	34.3	32.6	36.7	42.7	40.5	26.4	20.6	20.6	14.3
	(-20)-0	19.7	22.4	25.9	35.4	38.1	40.9	44.7	43.8	28.4	21.6	21.8	15.8
Kerman	0-20	32.9	33.5	44.9	**44.7**	**47.6**	48.5	49.7	**46.8**	40.7	36.9	29.8	27.4
	20-40	33.5	35.9	**45.6**	42.9	45.9	45.8	48.2	44.5	**41.8**	**38.6**	**31.7**	**29.1**
	40-60	**34.2**	**36.3**	41.9	39.8	44.2	42.8	45.4	41.8	37.4	34.6	29.3	26.4
	60-80	31.8	32.9	39.7	37.4	39.7	38.6	38.7	38.9	35.6	30.6	25.8	22.3
	80- (-80)	28.3	28.4	37.6	36.5	34.1	32.5	37.3	35.1	32.9	28.3	21.4	19.6
	(-80)-(-60)	29.5	30.8	38.6	37.5	38.6	37.4	39.6	37.4	33.2	29.6	22.5	21.9
	(-60)-(-40)	30.6	31.6	39.8	38.8	42.9	40.7	45.9	42.8	35.7	31.9	23.7	24.3
	(-40)-(-20)	31.6	32.1	41.7	41.9	46.5	46.9	47.7	44.4	38.6	34.2	26.4	26.5
	(-20)-0	32.7	33.4	44.6	44.2	47.3	**48.2**	**49.9**	46.7	40.8	36.7	29.6	27.5
Yazd	0-20	26.5	26.3	30.6	**34.1**	**45.7**	47.9	**48.6**	**43.2**	34.2	24.8	22.7	27.6
	20-40	27.4	27.4	**31.7**	32.8	43.9	46.7	45.3	41.8	**36.3**	**25.3**	**23.9**	**28.8**
	40-60	**28.2**	**29.8**	27.5	30.9	42.6	44.5	41.6	40.4	32.8	23.8	22.4	25.9
	60-80	23.9	25.8	25.8	26.7	40.8	40.3	40.2	39.7	30.9	21.6	20.8	23.7
	80- (-80)	20.6	18.7	23.9	23.4	36.6	38.8	39.1	37.3	28.6	18.9	17.5	20.3
	(-80)-(-60)	21.6	20.9	25.3	26.3	38.3	41.5	39.9	38.9	29.5	19.6	18.1	22.5
	(-60)-(-40)	22.8	22.6	27.7	29.7	41.9	45.2	40.2	40.8	30.9	21.5	19.3	23.7
	(-40)-(-20)	24.7	24.7	28.4	32.1	43.1	46.9	46.9	41.6	32.6	23.8	21.2	25.9
	(-20)-0	26.3	26.4	30.7	33.9	45.4	**48.2**	48.4	42.9	34.6	24.1	22.6	27.7

Table 3.The optimal slope in each city

Cities	Angle (Degree)	Power per a month (Watt)											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
Shiraz	49	46	30	15	2	-4	-1	12	26	41	50	54	28
Isfahan	55	52	36	21	8	1	4	18	33	47	55	56	33
Kerman	50	47	32	16	3	-3	-0.9	12	27	43	52	56	30
Yazd	52	48	32	16	4	-2	0.6	14	28	42	51	52	29

In [39], it shown that the maximum amount of yearly irradiation in these cities that was proposed in this paper, was for Yazd by 10391 MJ/m^2. Using NRI model shows that yearly irradiation calculated with better accuracy.
The panel's angle on the bench is 40 degrees to the south. According to Table 2, the extractable power in these four cities has been calculated. For better comparison, these values have been compared in 4 seasons of the year. Figure. 9 shows the power extracted from the bench in the four cities mentioned in the spring.

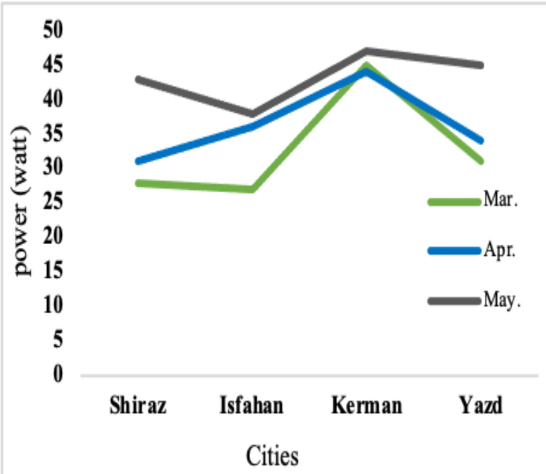

Figure 9. The power extracted in spring

It is clear that in May, the highest power level is observed in all four cities. It is noteworthy that Kerman has a higher capacity every three months. Figure. 10, 11, and 12 show the power available in summer, fall, and winter, respectively.

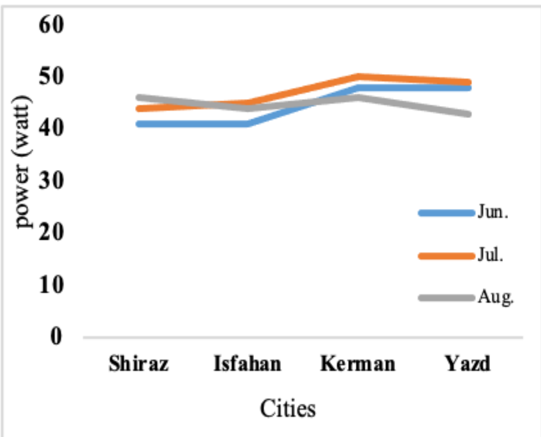

Figure 10. The power extracted in summer

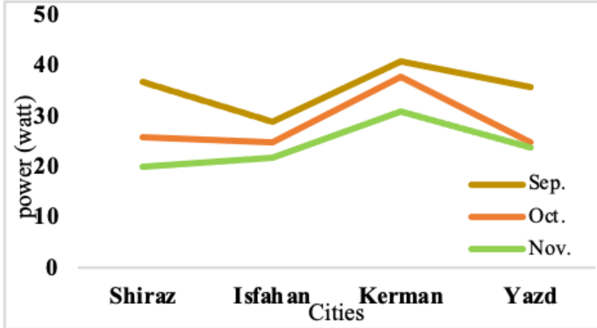

Figure 11. The power extracted in fall

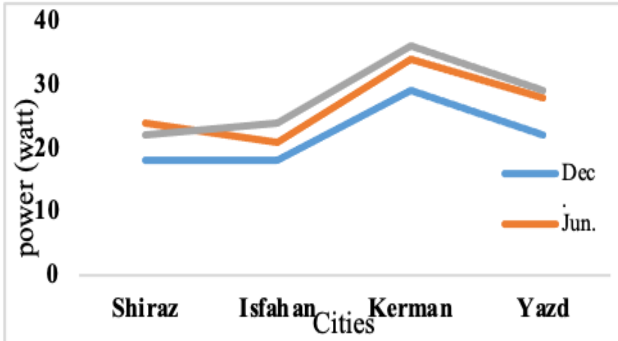

Figure 12. The power extracted in winter

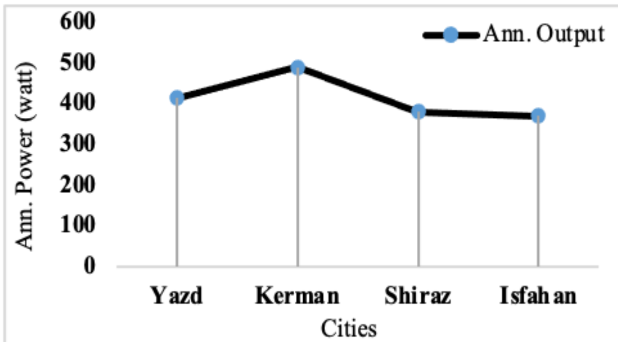

Figure 13. The annual extracted power

It can be seen that in Kerman, we can receive the highest amount of power throughout the year. Due to the location of this city, it was expected to have the highest amount. Considering that Kerman and Yazd are both located in tropical and rainy regions of Iran, they are among the best commercialization options for this bench. Also, although Shiraz and Isfahan ranked third and fourth in this comparison, each separately can be an excellent option to build more benches. Due to the tourist attractions that these two cities have, many tourists from these cities every year. They see that it significantly impacts people's awareness of the uses of solar energy. Figure. 13

shows the power that can be received annually from each solar bench in each city.

3.2. Limitations and Future works

The aim of this work was to create a smart multifunctional solar bench that can be a street furniture. The mentioned product can be used to meet night needs, electrical connection, internet and artificial lighting at a low cost. This solar furniture is fully functional anywhere in the world. According to the explanations in the previous sections, the existence of a continuous shade through the system of light sensors and the mechanical system leads to an increase in higher efficiency. However, this paper obtains the efficiency of the solar bench in all directions, but the existence of a tracker instead of a fixed panel allows the bench to rotate in one or two directions.

This bench has the ability to add more features than the current facilities, for example, it can be powered from the panels, and activate the advertising display or TV, or by making the rotation of the solar panel intelligent and the ability to determine the exact geographical location, it can be increased efficiency. By making such changes, the solar bench can be turned into a smart solar bench.

4. Conclusion

It this article, a solar bench was presented. The panel is placed at an angle of 40 degrees to the south. This bench has a beautiful design by body ergonomics and is affordable. Then, using the NRI radiometric model, direct and scattered radiation has been calculated for four cities of Shiraz, Kerman, Yazd, and Isfahan, which are the central cities of Iran and have the highest amount of radiation among other cities in Iran. The highest power received from the panel in these cities has also been calculated. According to the calculations, Kerman has the potential to receive the highest power. Some feature of the proposed work includes WiFi, Wired and wireless charging for tablets and mobile phones and two bicycles or electric scooters, 14 USB outputs, displaying the amount of air pollution time, date, and air temperature. It can includes music player or advertising system in future works. There is a Lighting system for using the bench at night.

Nomenclature

I	Total irradiation (W/m^2)
$I_{b,n}$	Beam irradiation intensity (W/m^2)
$I_{d,a}$	Diffused irradiation on a horizontal surface (W/m^2)
$I_{t,a}$	Total irradiation on an arbitrary plate (W/m^2)
ρ_{alb}	The reflection factor of the earth (surface)
$F_b(\delta)$	Beam irradiation on an arbitrary plate (W/m^2)
$F_d(\delta)$	Diffused irradiation on an arbitrary plate (W/m^2)
CF	Cloud factor
α	Altitude angle (Deg.)
θ	Incidence angle (Deg.)
δ	Declination angle (Deg.)
β	Tilt angle
C_{b1}, C_{b2}	Constant
C_{d1}, C_{d2}	Constant

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