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# Effect of Temperature Coefficient and Efficiency of PV Technologies On 3E Performance and Hydrogen Production of On-Grid PV System in A Very Hot and Humid Climate

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**A B S T R A C T**

Although hydrogen is in its early stages in Iran, its development capacity is high. Considering the importance of these issues, this paper examines for the first time the production of hydrogen from solar energy in the hot and humid climate of Iran. For this purpose, five stations have been selected in Khuzestan province, and using HOMER V2.81 software, the annual solar electricity production of a 20 kW power plant connected to the grid has been calculated considering five types of solar panels (Mono-Crystalline, Poly-Crystalline, CIGS, CdTe, Amorphous). Then, using analytical equations and a solid oxide electrolyzer, the annual hydrogen production has been calculated. The results showed that Amorphous technology is the most suitable in terms of cost, and CdTe technology is the most suitable in terms of energy production and pollutant reduction. In total, among the studied stations, Masjed-e Soleyman city had the highest electricity production, highest hydrogen production, highest $CO_2$ emission reduction prevention, and lowest cost per kWh produced with values of 37,492 kWh/year, 1,254.4 kg/year, 1,768 kg/year and $0.072/year respectively. Among the studied stations, Ahwaz was found to be the least suitable station.

## 1. Introduction

Amid the increasing worldwide energy demand, the production of hydrogen through photovoltaic technologies serves to meet this demand and concurrently contributes to greenhouse gas emission reduction. Nevertheless, the performance of these technologies is subject to various factors, such as

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temperature coefficient and efficiency [1]. In regions characterized by hot and humid climates, these factors can substantially affect the overall system efficiency. Consequently, it is imperative to examine and comprehend these factors to optimize system performance [2].

This holds particular significance for regions with elevated temperatures and high humidity levels, such as Southeast Asia, where solar hydrogen production could provide a viable alternative to fossil fuels. However, research on the influence of temperature coefficient and efficiency on solar hydrogen production in hot and humid climates [3, 4] has been notably lacking.

As of 2022, the global hydrogen production has reached approximately 50 million tons, with China leading as the largest producer, contributing 12.5 million tons annually. A substantial 88% of the world's hydrogen production is attributed to the petrochemical industry, while less than 10% is commercially traded [5, 6]. The shift towards green hydrogen is anticipated to persist, with an increasing number of nations and industries recognizing its promise as a clean energy source [7, 8]. Figure 1 illustrates a significant recent surge in solar energy production, underscoring its potential utility in hydrogen production [9].

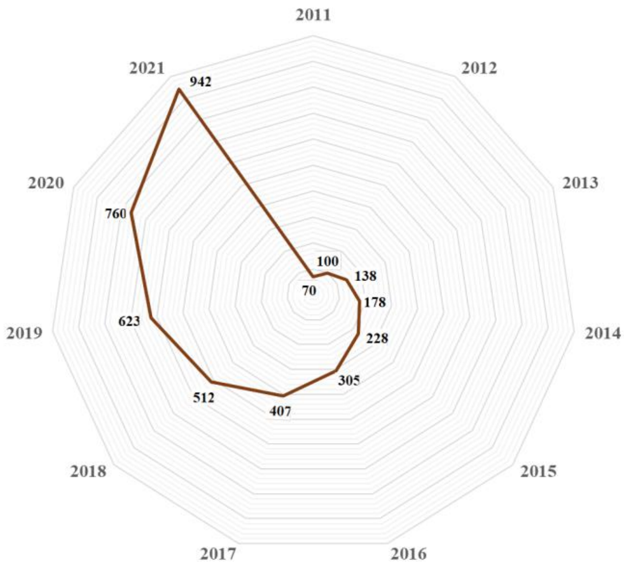



Figure 1. Changes in solar PV energy production from 2011 to 2021 [9].

Table 1 presents a selection of recent research carried out on the production of solar hydrogen worldwide [10-21]. The research reveals that certain studies have focused on the production of hydrogen from solar energy in particular regions [10, 11, 15, 18, 20]. Additionally, numerous other studies have employed statistical methods to compare hydrogen production across various renewable energy sources [12-14, 16, 17, 19, 21].

Table 1. Recent studies in the field of solar hydrogen production

| Year | Study Area | Energy resources | Method | Topic Focused on | Result | Difference with current work |
|---|---|---|---|---|---|---|
| **2023 Present work** | Khuzestan, Iran | Solar | HOMER V.2.81 and analytical method | PV-hydrogen generation by water electrolysis | - In terms of economics, Amorphous is the most suitable, and CdTe is the most suitable in terms of energy production and pollutant reduction. -Masjed-e Soleyman and Ahwaz are the most suitable and most unsuitable stations, respectively. | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| **2023 [10]** | India | Solar | Analytical method | generation of hydrogen from industrial wastewater | This method offers benefits in terms of its favourable environmental impact besides considerable economic advantage | -Financial and environmental calculations have not been done.<br>-The most suitable station has not been checked.<br>-The methodology of hydrogen production calculations is different from the present work.<br>-Different solar cell technologies have not been investigated. |
| **2023 [11]** | Iraq | Solar | A mathematical model using MATLAB/Simulink | the optimum site for solar hydrogen production systems can be established in Iraq | Rutba and Basra generates the highest and lowest hydrogen and oxygen, respectively. | -The solar system under investigation is not connected to the grid.<br>-Financial and environmental calculations have not been done.<br>-The methodology of hydrogen production calculations is different from the present work.<br>-Different solar cell technologies have not been investigated. |
| **2023 [12]** | Iran | Solar, Wind, Biomass | HOMER V.2.81 | Supply electricity for hospital hydrogen generators | The lowest LCOE is 0.251 $ and 3% of electricity is supplied by diesel generator. | - The climate under investigation was different.<br>- Various stations were not compared.<br>- Different solar cell technologies were not compared.<br>- The objective of the study was different.<br>- The scale of power supply was different. |
| **2023 [13]** | Morocco | PV, Fuel cell | System Advisor Model and MATLAB | Optimization of size and cost of solar-based system | The optimal electricity price was equal to 0.95657 $/kWh. | - The climate under investigation was different.<br>- Various stations were not compared.<br>- Different solar cell technologies were not compared.<br>- The objective of the study was different.<br>- The scale of power supply was different. |
| **2022 [14]** | Jordan | Solar, Wind, Hybrid Solar-Wind | Analytical method | explore the potential of employing planned 100% renewable energy systems for the parallel production of green hydrogen fuel | - PV-based system has the highest demand-supply fraction (>99%).<br>- The wind-based system is more favorable economically. | -Different solar cell technologies have not been investigated.<br>-The most suitable station has not been checked. |
| **2022 [15]** | China | Solar | Aspen Plus | Comprehensive evaluation of three hydrogen production methods by solar energy | The method of using a PEM electrolyzer using photothermal electricity generation has significant environmental benefits. | -Different solar cell technologies have not been investigated.<br>-The most suitable station has not been checked.<br>- The issue of connecting to the grid has not been discussed.<br>-The methodology of hydrogen production calculations is different from the present work. |
| **2022 [16]** | Dhahran, Saudi Arabia | Solar, wind | MATLAB software | Hydrogen production from excess electricity of an off-grid wind-solar hybrid system | The minimum cost of hydrogen production is \$36.32/kg, and the investigated system has prevented the emission of 9.66 tons of $CO_2$ per year. | -Different solar cell technologies have not been investigated.<br>-The most suitable station has not been checked.<br>-The issue of connecting to the grid has not been discussed.<br>-The methodology of hydrogen |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | production calculations is different from the present work. |
| **2022 [17]** | Helmand province, Afghanistan | Solar, Wind | Stepwise Weight Assessment Ratio Analysis And Multi-Criteria Decision - Making | Techno-econo-enviro analyses of hydrogen production from wind/solar | The most suitable place for generating solar electricity and hydrogen is LaskarGah station and for generating wind electricity and hydrogen is Sangin station. | -Different solar cell technologies have not been investigated.<br>-The issue of connecting to the grid has not been discussed.<br>-The methodology of hydrogen production calculations is different from the present work. |
| **2023 [18]** | Turkey | Solar | Data collection | Preparation of solar hydrogen maps for Turkey | Erzurum, Konya, Sivas, and Van are found to be the highest hydrogen production potentials | - Only 2 types of solar cell technology have been investigated.<br>- The issue of connecting to the grid has not been discussed.<br>- The methodology of hydrogen production calculations is different from the present work.<br>- The survey scale is national and not regional.<br>-Financial and environmental calculations have not been done. |
| **2023 [19]** | Iran | Ocean thermal, Solar, Wind | Mathematical modelling | Proposing a novel integrated system based on ocean thermal, solar and wind energy | Exergy efficiency increased by 19% and hydrogen production by 1.14 kg/hour. | -Different solar cell technologies have not been investigated.<br>-The methodology of hydrogen production calculations is different from the present work.<br>-The most suitable station has not been checked.<br>-Environmental calculations have not been done. |
| **2022 [20]** | Uzbekistan | Solar | Multi-Criteria Decision -Making method | Locating solar hydrogen production in 13 provinces | With the annual production of 24.92 tons of solar hydrogen, all ranking methods identified Bukhara province as the most suitable place. | -Different solar cell technologies have not been investigated.<br>-The ranking methodology of the investigated stations is different from the present work.<br>-The survey scale is national and not regional.<br>-Financial and environmental calculations have not been done.<br>-The issue of connecting to the grid has not been discussed. |
| **2022 [21]** | Iraq | Solar, Wind | levelized cost method | Investigating the sensitivity analysis on the equipment of different wind-solar system configurations in the field of hydrogen production | The maximum amount of hydrogen production in Basra was produced at a cost of 0.752 $\$/m^3$. | -Only 2 different solar cell technologies have been investigated.<br>-The ranking methodology of the investigated stations is different from the present work.<br>-The scale of the survey was not regional.<br>-Environmental calculations have not been done.<br>-The issue of connecting to the grid has not been discussed. |

Despite the extensive research conducted in the field of hydrogen production using solar energy, it has been determined by examining the history of this research that the impact of temperature coefficient and efficiency of PV technologies on solar hydrogen production in hot and humid climates has not been investigated. Additionally, potential strategies to enhance system performance under these conditions have not been discussed. Therefore, this study is the first to investigate five different solar cell technologies in five distinct cities within the Khuzestan province. Solar electricity generated by a 20-kilowatt power plant has been computed using HOMER V2.81 software. Subsequently, hydrogen production via water electrolysis has been calculated using analytical equations. The results of this study can offer valuable insights for designing efficient solar-hydrogen generation systems that can effectively operate in hot and humid climates.

## 2. The area under study

Khuzestan, which covers an area of 64,057 $km^2$ and has a hot and humid climate, is the largest province in the western part of Iran (Figure 2) [22]. Despite the reduction in efficiency of solar power plants in this province due to the hot air, Khuzestan province is generally considered to have a suitable capacity for utilizing solar energy due to its strong sun radiation [23].

The stations examined in this study are Abadan, Ahwaz, Bandar-e Mahshahr, Dezful, and Masjed-e Soleyman. The data from these stations, which have an average age of 20 years, were obtained from the NASA website. The geographical coordinates and population of the stations under investigation are provided in Table 2.

Table 2. Location information and population of the investigated stations [24]

| Station | Longitude | Latitude | Height above sea level (m) | Population in 2016 |
|---|---|---|---|---|
| Abadan | 48.3 | 30.4 | 6 | 231476 |
| Ahwaz | 48.7 | 31.3 | 22 | 1185000 |
| Bandar-e Mahshahr | 49.2 | 30.7 | 46 | 162797 |
| Dezful | 48.5 | 32.4 | 503 | 264709 |
| Masjed-e Soleyman | 49.3 | 32.0 | 406 | 100497 |


Figure 2. The studied area in the southwest of Iran

## 3. Methodology

This paper discusses the simulation of a solar system that is connected to the grid using HOMER software. The methodology used in this study involves designing and simulating the solar system, which includes collecting data, determining the system size, and identifying the necessary parameters for simulation.

The first step in this process is gathering data about the project's location. This information includes the longitude, latitude, and time zone of the specific location being investigated. Additionally, monthly average data on solar radiation and air temperature are also required for accurate simulation.

The second step involves determining the size of the solar system based on the energy needs of the station being considered. This includes selecting appropriate components such as solar panels, inverters, and connecting to the national electricity grid. Factors like maximum load requirements and expected energy production by the solar panels should be taken into account during this step. The final part of this step involves determining the price and technical specifications of the equipment to be used.

Once all parameters from the first two steps are determined, simulations are conducted using software to evaluate how well the proposed solar system performs under different conditions. The objective is to minimize costs while meeting energy requirements (Figure 3).

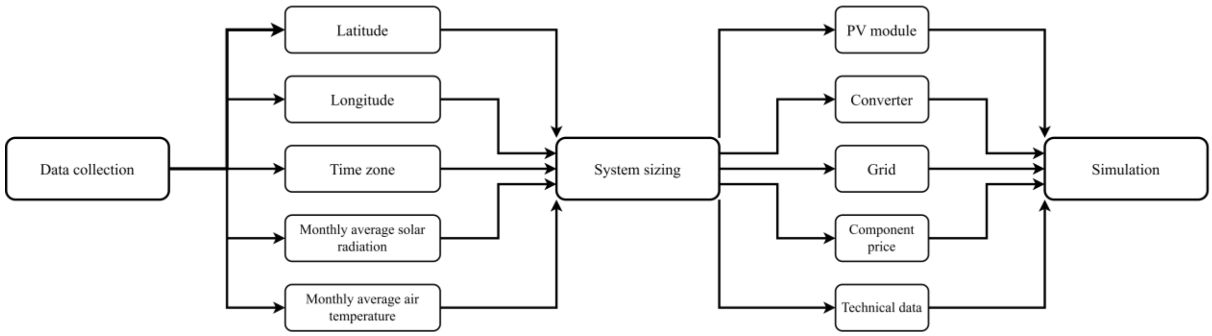


Figure 3. Software performance diagram in different stages

The governing equations of the problem are the amount of electricity produced by solar cells and the way the studied solar system exchanges electricity with the grid, which are given in equations 1 and 2, respectively [25, 26]:

$$P_{PV} = Y_{PV} f_{PV} \frac{\overline{H_T}}{\overline{H_{T,STC}}} \tag{1}$$

$$C_{grid,energy} = \sum_{i}^{rates} \sum_{j}^{12} \begin{cases} E_{net\,grid\,purchases,i,j}\, c_{power,i} \\ if \;\; E_{net\,grid\,purchases,i,j} \geq 0 \\ \\ E_{net\,grid\,purchases,i,j}\, c_{sellback,i} \\ if \;\; E_{net\,grid\,purchases,i,j} \prec 0 \end{cases} \tag{2}$$

The amount of hydrogen produced by solar cells is obtained based on equation 3 [27]:

$$M_{H_2} = \frac{P_{PV} \times \eta_{ele}}{HHV_{H_2}} \tag{3}$$

After calculating the solar electricity produced by different solar cells through simulations using HOMER software, the amount of hydrogen produced is determined by incorporating it into the aforementioned equation through numerical analyses. It should be noted that the electrolyzer efficiency and the higher heating value of hydrogen significantly impact the amount of produced hydrogen.

HOMER software uses the equation 4 to compute the cost of each generated kWh of electricity (COE) [28].

$$COE = \frac{C_{ann,tot}}{E_{load\ served}} \tag{4}$$

Concerning losses, it should be noted that based on the electricity passing through the electrical converter and according to the converter's efficiency, losses will be calculated.

$$Converter\ losses = E_{in} - E_{out} = E_{in}(1 - \eta_{Conv}) \tag{5}$$

Figure 4 illustrates the system under examination. As evident, the system is connected to the national power grid and sells surplus electricity to it while directing the required power for hydrogen production towards the electrolyzer. The electrical converter is responsible for converting DC power to AC.

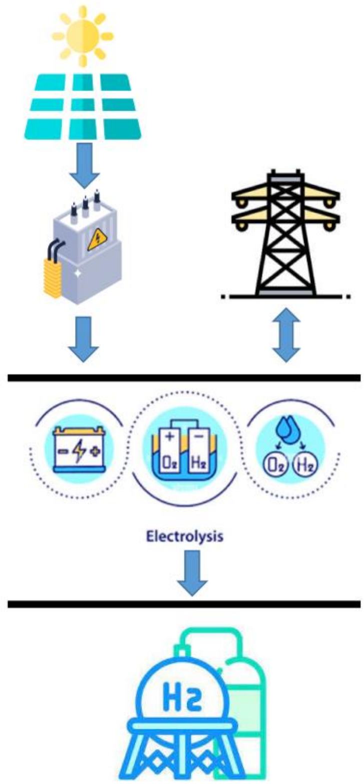


Figure 4. The schematic of the system under study in the current work

## 4. Input data

The information on the solar cells used is presented in Table 3. Five common solar cell technologies in the Iranian market were utilized for the assessments. This was done to demonstrate to investors, experts, and decision-makers in the energy sector the extent of differences between various technologies from economic, energy, and environmental standpoints. The advantage of this examination lies in the fact that the results of this study can serve as a roadmap for decision-making regarding the development of solar power plants in extremely hot and humid climates.

Figure 5 presents the data of solar radiation, air clearness index and ambient temperature for 5 stations. Other required information, which includes price information and technical information of the equipment used, is listed in Table 4.

Table 3. Technical and price information of used solar cells

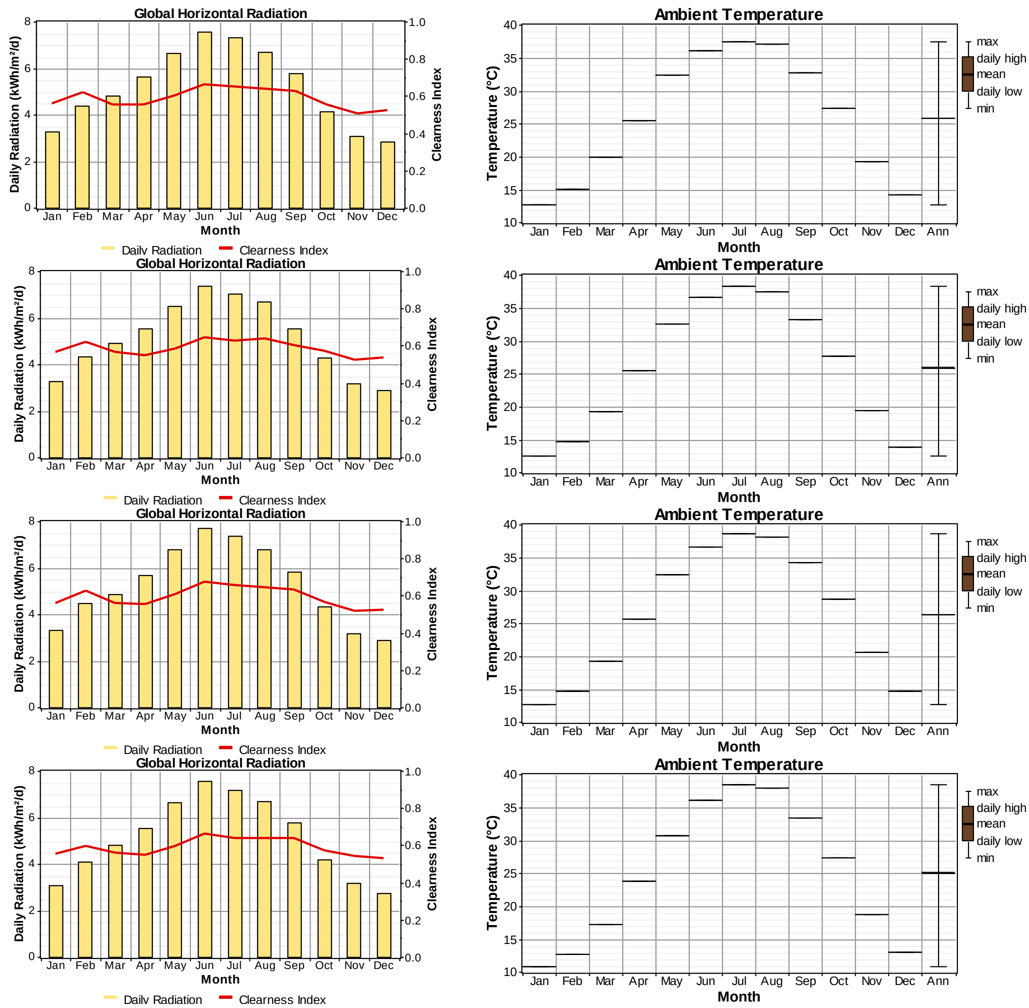
| PV types | Lifetime (years) | Price ($/kW) | Temperature coefficient [29] | Standard test condition performance (%) [29] |
|---|---|---|---|---|
| Mono-crystalline | 25 [30] | 950 [31] | - 0.45 | 13.75 |
| Poly-crystalline | 25 [32] | 850 [31] | - 0.45 | 12.5 |
| CIGS | 20 [33] | 2000 [34] | - 0.365 | 11.5 |
| CdTe | 20 [35] | 1050 [36] | - 0.25 | 10.5 |
| Amorphous | 20 [37] | 800 [38] | - 0.365 | 12 |

a)

b)

c)

d)



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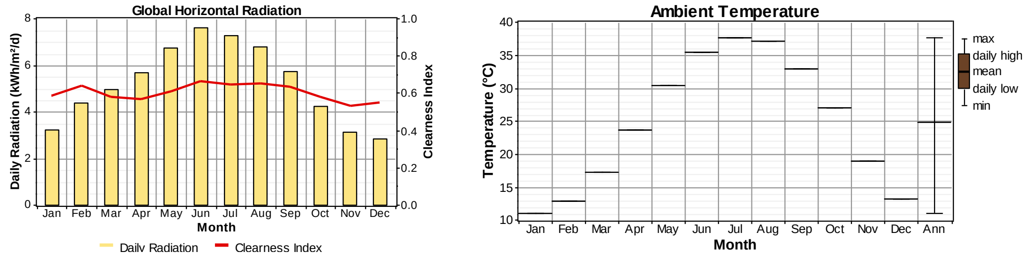


Figure 5. Information on solar radiation, air clearness index and ambient temperature for the investigated stations a) Abadan b) Ahwaz c) Bandar-e Mahshahr d) Dezful e) Masjed-e Soleyman

Table 4. Technical and price information of the used equipment and system under review

| Equipment | Information |
|---|---|
| Converter | $\eta_{inv} = 90\%$ , $\eta_{rec} = 85\%$ , Purchase and replacement cost: 200 \$ Operating and maintenance cost: 10 \$, Lifetime: 10 year [39] |
| Grid | Purchase price: 0.002 \$/ kWh, Sale price: 0.034 \$/kWh, Emissions (g/kWh): $CO_2$=632, $SO_2$=2.74, and $NO_x$=1.34 |
| Emission penalty | $CO_2$: 3.1 \$/ton, CO: 57 \$/ton, $SO_2$: 560 \$/ton, $NO_x$: 184\$/ton [40] |
| Annual interest rate | 18% [41] |
| Project lifetime | 25 year [42] |
| Solar cells | Derating factor: 90%, Slop: Equal to latitude [43], Azimute: 0°, Ground reflectance: 20%, Purchase and replacement cost: According to Table 3, Operating and maintenance cost: 10% of purchase price [44], Lifetime: According to Table 3 |

## 5. Results

The results of technical, economic, and environmental analyses for the Abadan station are presented in Table 5. According to the findings, the most favorable economic scenario is the utilization of Amorphous type solar cells. In this scenario, the cost of producing each kilowatt-hour (kWh) of electricity through the solar cell-grid system is \$0.073. The reason behind this low electricity production cost is the comparatively inexpensive nature of this particular solar cell technology when compared to other technologies.

The second-best economic scenario, from a financial standpoint, involves employing Poly-crystalline technology. However, this option is 4.1% more expensive than the best scenario mentioned earlier.

In terms of solar energy production and its subsequent reduction in environmental pollutants, CdTe technology proves to be the most suitable scenario. It yields a total production of 42,481 kWh/year of solar electricity and prevents the emission of 493 kg/year of $CO_2$ pollutants. One of the reasons for CdTe technology's superiority in terms of energy production is its low sensitivity to temperature (low-temperature coefficient) when compared to other technologies. This stands in contrast to mono-crystal and poly-crystal technologies.

The highest sales of electricity to the grid, the lowest purchase of electricity from the grid, the highest capacity factor, and the highest surplus electricity are all associated with CdTe technology. This is because CdTe technology produces more solar electricity compared to other technologies, but it also has higher converter losses. Additionally, it is worth noting that the ROI for CIGS technology is negative. This is because at the end of year 25, the cumulative nominal cash flow is lower than year zero due to the expensive price of electricity production in this scenario.

Table 5. Results of simulation for Abadan

| PV technology | COE (\$/kWh) | PV production (kWh/year, %) | Excess electricity (kWh/year) | Capacity factor (%) | Inverter losses (kWh/year) | Grid pyrchased (kWh) | Sold (kWh) | $CO_2$ emission (kg/year) | Return on investment (%) | Hydrogen (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|
| Amorphous | 0.073 | 36271, 69% | 5860 | 20.7% | 3041 | 16039 | 16764 | -459 | +0.853 | 1213.5 |
| Cd Te | 0.095 | 36477, 69% | 6004 | 20.8% | 3048 | 16033 | 16814 | -493 | +0.241 | 1220.4 |
| CIGS | 0.182 | 36269, 69% | 5858 | 20.7% | 3041 | 16039 | 16764 | -458 | -0.777 | 1213.5 |
| Mono-crystaline | 0.085 | 3126, 69% | 5761 | 20.6% | 3037 | 16043 | 16727 | -432 | +1.3 | 1208.7 |
| Poly-crystaline | 0.076 | 36118, 69% | 5755 | 20.6% | 3037 | 16043 | 16725 | -431 | +1.43 | 1208.4 |

Table 6 presents the results of technical, economic, and environmental analyses for Ahwaz station. The results show that various technologies exhibit similar behavior to Abadan station in terms of economics, energy, and environment. However, Ahwaz has lower average radiation and higher average temperature compared to Abadan. Therefore, Abadan is considered superior to Ahwaz in terms of energy and economy.

Table 6. Results of simulation for Ahwaz

| PV technology | COE ($/kWh) | PV production (kWh/year, %) | Excess electricity (kWh/year) | Capacity factor (%) | Inverter losses (kWh/year) | Grid pyrchased (kWh) | Sold (kWh) | $CO_2$ emission (kg/year) | Return on investment (%) | Hydrogen (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|
| Amorphous | 0.073 | 36191, 69% | 5818 | 20.7% | 3038 | 16045 | 16736 | -436 | +0.847 | 1210.9 |
| Cd Te | 0.096 | 36393, 69% | 5956 | 20.8% | 3044 | 16039 | 16788 | -473 | +0.237 | 1217.6 |
| CIGS | 0.182 | 36188, 69% | 5816 | 20.7% | 3037 | 16045 | 16735 | -436 | -0.780 | 1210.8 |
| Mono-crystaline | 0.085 | 36048, 69% | 5725 | 20.6% | 3033 | 16050 | 16696 | -408 | +1.29 | 1206.1 |
| Poly-crystaline | 0.077 | 36040, 69% | 5719 | 20.6% | 3032 | 16050 | 16694 | -407 | +1.43 | 1205.8 |

Table 7 provides the results of technical, economic, and environmental analyses for Bandar-e Mahshahr station. This station has higher average monthly radiation compared to Abadan but also higher average monthly temperature. As a result, Bandar-e Mahshahr is considered superior to Abadan in terms of economy and energy. In other words, the positive impact of higher radiation intensity outweighs the negative impact of high temperature.

The results of technical, economic, and environmental analyses for the Dezful station are presented in Table 8. It should be noted that the average monthly radiation for this station is similar to Ahwaz, but the average monthly temperature is lower. As a result, the findings indicate that Dezful outperforms Ahwaz in terms of economy, energy, and environment.

Table 7. Results of simulation for Bandar-e Mahshahr

| PV technology | COE ($/kWh) | PV production (kWh/year, %) | Excess electricity (kWh/year) | Capacity factor (%) | Inverter losses (kWh/year) | Grid pyrchased (kWh) | Sold (kWh) | $CO_2$ emission (kg/year) | Return on investment (%) | Hydrogen (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|
| Amorphous | 0.072 | 36702, 70% | 5973 | 20.9% | 3073 | 15975 | 16986 | -639 | +0.902 | 1227.9 |
| Cd Te | 0.095 | 36932, 70% | 6133 | 21.1% | 3080 | 15969 | 17043 | -679 | +0.280 | 1235.6 |
| CIGS | 0.181 | 36699, 70% | 5971 | 20.9% | 3073 | 15975 | 16985 | -638 | -0.756 | 1227.8 |
| Mono-crystaline | 0.084 | 36539, 70% | 5863 | 20.9% | 3068 | 15980 | 16943 | -609 | +1.34 | 1222.5 |
| Poly-crystaline | 0.076 | 36531, 70% | 5857 | 20.9% | 3068 | 15980 | 16942 | -608 | +1.48 | 1222.2 |

Table 8. Results of simulation for Dezful

| PV technology | COE ($/kWh) | PV production (kWh/year, %) | Excess electricity (kWh/year) | Capacity factor (%) | Inverter losses (kWh/year) | Grid pyrchased (kWh) | Sold (kWh) | $CO_2$ emission (kg/year) | Return on investment (%) | Hydrogen (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|
| Amorphous | 0.073 | 36371,69 % | 5941 | 20.8% | 3043 | 16049 | 16792 | -470 | +0.859 | 1216.9 |
| Cd Te | 0.095 | 36548,69% | 6066 | 20.9% | 3049 | 16045 | 16834 | -499 | +0.244 | 1222.8 |
| CIGS | 0.182 | 36369,69% | 5939 | 20.8% | 3043 | 16049 | 16792 | -469 | -0.775 | 1216.8 |
| Mono-crystaline | 0.085 | 36248,69% | 5857 | 20.7% | 3039 | 16052 | 16760 | -447 | +1.30 | 1212.8 |
| Poly-crystaline | 0.076 | 36240,69% | 5851 | 20.7% | 3039 | 16052 | 16758 | -446 | +1.44 | 1212.5 |

Table 9 provides the results of technical, economic, and environmental analyses for the Masjed-e Soleyman station. The behavior of different solar cell technologies at this station is consistent with that observed at other stations. Specifically, Amorphous technology is found to be the most cost-effective option, while CdTe technology excels in terms of energy efficiency and environmental impact. In comparison to Bandar-e Mahshahr, it should be noted that although the average annual radiation is slightly lower at Masjed-e Soleyman station, the average annual temperature is also lower. Based on these results, it can be concluded that the positive impact of temperature reduction outweighs the negative impact of radiation reduction. Consequently, Masjed-e Soleyman station emerges as the most suitable location in Khuzestan province for utilizing solar energy in hydrogen production.

Table 9. Results of simulation for Masjed-e Soleyman

| PV technology | COE ($/kWh) | PV production (kWh/year, %) | Excess electricity (kWh/year) | Capacity factor (%) | Inverter losses (kWh/year) | Grid pyrchased (kWh) | Sold (kWh) | $CO_2$ emission (kg/year) | Return on investment (%) | Hydrogen (kg/year) |
|---|---|---|---|---|---|---|---|---|---|---|
| Amorphous | 0.072 | 37329,70% | 6280 | 21.3% | 3105 | 15927 | 17226 | -821 | +0.954 | 1248.9 |
| Cd Te | 0.091 | 37492,70% | 4779 | 21.4% | 3272 | 15924 | 18721 | -1768 | +0.457 | 1254.4 |
| CIGS | 0.180 | 37326,70% | 6278 | 21.3% | 3105 | 15927 | 17226 | -821 | -0.734 | 1248.8 |
| Mono-crystaline | 0.084 | 37215,70% | 6202 | 21.2% | 3102 | 15930 | 17198 | -801 | +1.38 | 1245.1 |
| Poly-crystaline | 0.075 | 37207,70% | 6195 | 21.2% | 3101 | 15930 | 17196 | -800 | +1.53 | 1244.8 |

Figure 6 illustrates the cost graph for Masjed-e Soleyman station and the Amorphous technology (economically superior scenario). It is evident from the figure that in the 10th and 20th years, the cost of replacing solar cells imposes a significant financial burden on the system. Selling electricity to the grid incurs a positive cost over the 25-year period, and in the 25th year, i.e., the end of the project, the sale of usable equipment as salvage cost slightly reduces the system's expenses.

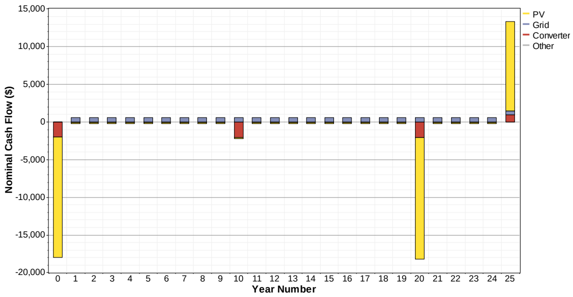


Figure 6. Nominal cash flow diagram of economically superior scenario

Figure 7 displays the amount of power required in the first three days of the year, the electricity generated by the solar cells, and the surplus electricity for the Masjed-e Soleyman station and CdTe solar cell technology (superior energy production scenario). The results indicate surplus electricity during peak sunlight hours when solar panels generate excessive power, resulting in surplus electricity as the generated electricity exceeds consumption. During darker hours, electricity purchase from the grid is necessary.

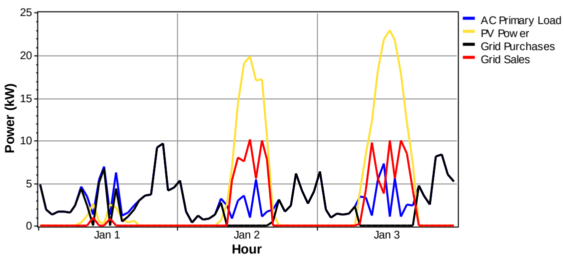


Figure 7. Power-Hour diagram for superior energy production scenario

## 6. Conclusion

One of the requirements for simulation is to examine different scenarios in order to identify the most efficient and cost-effective solution for meeting energy needs using renewable energies, while also reducing reliance on grid electricity. Considering the importance of this, in this study, we have investigated, for the first time, the effect of temperature coefficient and efficiency of different solar cell technologies using HOMER V2.81 software. We then evaluated the amount of solar hydrogen produced using the SE-type electrolyzer through analytical methods. The evaluation was conducted in 5 cities of Khuzestan province, where a 20Kw power plant connected to the grid was assessed at each location. The results of our investigations are as follows:

• The use of Amorphous technology has resulted in the lowest cost of electricity (0.072 $/kWh) among the stations that were studied.

• Among the stations that were studied, CdTe technology has resulted in the highest electricity (37492 kWh/year) and hydrogen (1254.4 kg/year) production.

• Masjed-e Soleyman station is considered the most suitable, while Ahwaz station is considered the least suitable among the stations that were investigated.

• In all of the investigated stations, the highest solar electricity production is approximately 184 MWh, and hydrogen production is approximately 6.151 tons per year, which is achieved through the use of CdTe technology.

• By generating solar electricity and reducing reliance on electricity from the national grid, as well as minimizing pollutant emissions, approximately 3.9 tons per year of $CO_2$ emissions are prevented in the best case scenario.

• The average cost per kWh of electricity produced in the investigated stations is $0.0726 in the best case scenario.

• Masjed-e Soleyman station has achieved the highest percentage of electricity supplied by solar cells, accounting for 70% of its total energy supply.

In the future and as a continuation of the current work, it is plausible to examine other climates in Iran. This exploration could reveal how different solar cell technologies impact various climates and whether the differences in results regarding energy, environmental, and economic parameters are more or less significant across different climates.

| **Nomenclature** | |
|---|---|
| $C_{sell\ back}$ | The sellback rate ($/kWh) |
| $E_{net\ grid\ purchases}$ | The net grid purchases (grid purchases minus grid sales) (kWh) |
| $Y_{PV}$ | Output power of solar cell under standard conditions (kW) |
| $P_{PV}$ | Output power of PV cells (kW) |
| $C_{power}$ | The grid power price ($/kWh) |
| $C_{ann,total}$ | Total annual cost ($) |
| $f_{PV}$ | Derating factor (%) |
| $C_{grid,\ energy}$ | Total annual energy charge (kWh) |
| $E_{load\ served}$ | Real electrical load by system (kWh/year) |
| *3E* | Energy-Economic-Environment (-) |
| $\overline{H_T}$ | Incident radiation on the cell’s surface on a monthly basis (kW/m$^2$) |
| $\overline{H_{T,STC}}$ | Incident radiation on the cell’s surface under standard conditions (1 kW/m$^2$) |
| | Mass of hydrogen (kg/year) |
| $HHV_{H2}$ | Higher heating value of the hydrogen (kWh/kg) |
| $\eta ele$ | Electrolyzer efficiency (%) |
| *PV* | Photovoltaic (-) |
| *NPC* | Net present cost ($) |
| *LCOE* | Levelized cost of electricity ($/kWh) |

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