Cost-Effective PV System Design Empowered by Mobile-Based Forecasting Application

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Abstract

As a result of advances in manufacturing techniques and battery longevity, photovoltaic system costs have decreased while efficiency of solar panels has increased. Cost reduction in both conventional and renewable energy systems depend on effective energy management. To determine how an energy management system for solar systems affects cost-reduction, this study introduces one. Starting by researching and analyzing the solar energy systems and find the parameters that affecting the high cost of the systems, trying to control the parameter that could be controlled, that leads to reduction will be around 30% of use1 saving day as a replacement for 1.5, 46.5% when 1 instead of 2 days, and 62.9% of uses 1 instead of 3 days. To further decrease solar energy system costs, this project utilizes weather forecasting to predict energy production. It implements energy management techniques to optimize energy usage and minimize the need for storage. By optimizing energy consumption, the goal is to enhance solar energy accessibility and affordability for consumers.

Keywords
Solar system, saving days, solar irradiance, weather forecasting, and Energy management.

1. Introduction
To achieve its energy demands, the United Arab Emirates (UAE) heavily relies on nonrenewable energy sources, mainly oil. However, there are a number of reasons why the UAE should switch to renewable energy:
The UAE's hot and dry environment makes it an ideal location for solar energy. The UAE may lessen its dependency on fossil fuels by using solar energy, which is a clean, plentiful, and sustainable energy source. Additionally, the price of renewable energy has been dropping in recent years, making it more affordable than conventional fossil fuels. And during the past ten years, the cost of solar energy in particular has fallen precipitously. Since 2010, the cost of solar panels has decreased by more than 85%. Consequently, one of the most economical sources of renewable energy is solar electricity. In many regions of the world, the cost of building new utility-scale solar power facilities is now comparable to the cost of building new fossil fuel power plants. The region will require more and more energy as a result of the cost being highly correlated with the amount that must be generated. So, in order to move the reduction ahead and make solar energy suitable for everyone, the cost of PV models must not grow in order to make the system smarter by including weather forecast and energy management system.

1.1 Objectives
The project is structured into two primary stages, each with distinct objectives. In the first stage, the focus is on designing the solar system. This entails conducting cost calculations and identifying the key parameters that will influence the implementation of the system. Moving on to the second stage, the aim is to optimize the system's cost

without compromising its ability to power the home. To achieve this, weather predictions are utilized to estimate the anticipated energy consumption. By incorporating a mobile-based application, the project aims to build the solar energy system based on the best-case scenario of energy savings, as opposed to relying on worst-case assumptions. This approach takes into account the weather forecast, enabling more accurate predictions and better control over energy usage. By utilizing weather forecasts and implementing an efficient energy management system, the project seeks to maximize the cost-effectiveness of the solar energy system while ensuring reliable power supply for the home.

2. Literature Review

In isolated locations where a grid connection is neither practical nor cost-effective, stand-alone solar energy systems are frequently employed. asserts that the availability of solar resources, system efficiency, and load demand must all be carefully taken into account when designing and optimizing stand-alone solar energy systems. For standalone solar energy systems, researchers have looked at a variety of optimization approaches, including size optimization, load matching, and battery storage optimization. With the aid of the solutions, the system's initial cost could be reduced and its performance could be improved. Grid-connected solar energy systems are becoming more and more popular as a way to reduce our reliance on fossil fuels and greenhouse gas emissions.

Grid-connected systems use solar energy to supplement or totally replace the grid's energy supply. According to [13], when integrating solar energy into the grid, special consideration must be given to a number of factors, including grid stability, power quality, and energy management. Three energy management techniques have been investigated for grid-connected solar energy systems: peak sun, load shifting, and demand response. These energy management techniques might reduce energy costs while boosting system reliability and stability. Effective energy management is necessary to realize the benefits of solar energy in standalone and grid-connected systems. According to, energy management techniques may be used to improve system performance and cut energy costs. Researchers have examined a variety of energy management techniques for solar energy systems, including load forecasting, battery management, and optimization algorithms.

These energy management techniques could reduce energy costs while increasing the efficiency of the system. Weather forecasting is a crucial method for enhancing the efficiency of solar energy installations. argues that accurate weather forecasting may be used to improve system performance by anticipating solar irradiation. Researchers have looked at a variety of weather prediction techniques for solar energy systems, including machine learning algorithms, statistical models, and numerical weather prediction models. These techniques for forecasting the weather might improve the accuracy of predictions of solar irradiance and lower the uncertainty of solar energy output.

3. Methods

The researchers used an MS Excel spreadsheet to determine how many devices would be needed and how often, and then they used the MIT app creator to develop the application with a controlling unit. The study was conducted using real-time devices that are now available on the market, and the literature was gathered from many databases, including IEEE journal and ELSEVIER.

4. Data Collection

The data of the solar systems have been collected by the units available in the UAEs market, the data of the irradiance have been taking from visual crossing weather data and enterprise analysis tools to data scientists, business analysts, professionals, and academics.

5. Implementation

The main components required to set up a standalone solar energy system. For a standalone system, the main components include PV modules, a battery bank, voltage regulator, and inverter as shown in Figure 1. However, for a grid-connected system as Figure 2 shows, the design is different as the PV modules are connected to the main utility grid via an inverter, allowing users to generate excess energy that can be sold back to the government grid.
To implement the best solar energy system, two models were considered: the stand-alone system and grid-connected systems. The essential components required for both models. In addition, sensors will be added throughout the home to optimize the system's performance.

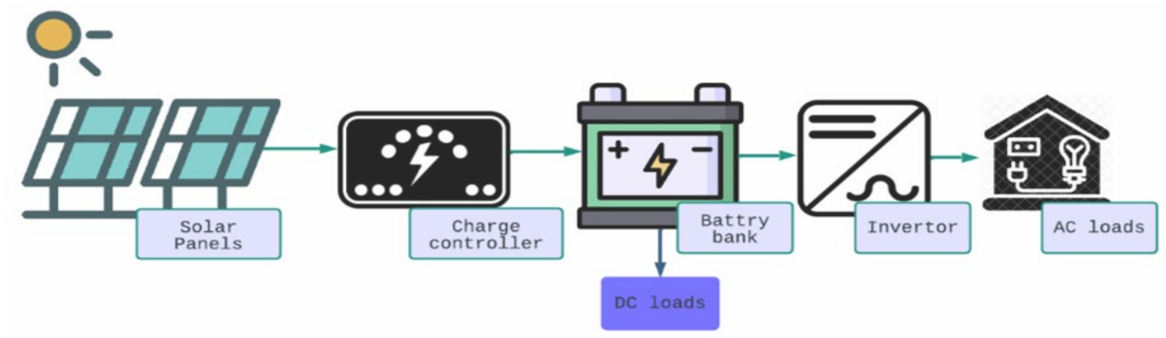

Figure 1. Stand-alone system

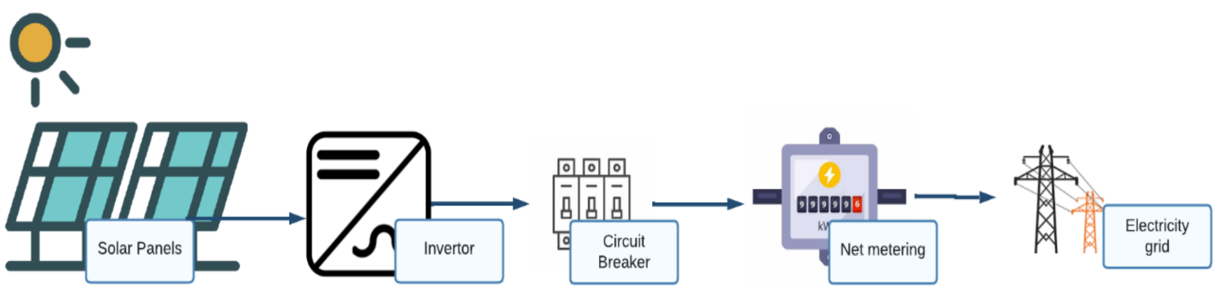

Figure 2. Grid-connected system

The design starts by calculating how many energies needed? For our case study Table 1 shows tabulated the loads, power, consume hours and energy.

Table 1. Example of home's load

#	Load	Hours	Power (watt)	Energy (kWh)
1	TV	2	58.6	0.1172
2	Light	10	12	0.6
3	Air condition	8	1000	24
4	Kettle	0.5	180	0.09
5	Coffee maker	0.3	850	0.255
6	Dishwasher	1.5	1200	1.8
7	Microwave	0.5	800	0.4
8	Air Frayer	1	1500	1.5
9	Toaster	0.3	700	0.21
10	Food processor	0.2	800	0.16
11	Refrigerator	-	-	1.26
12	Hair dryer	0.5	2200	1.1
13	Washing machine	1.5	400	0.6
14	Heater	0.5	1200	0.6

Therefore, for the same energy have been construct stand-alone and grid-connected, the answer is based on many parameters that will highly affect the number of (PV, batteries, invertor, and the voltage regulator), the parameters are concludes into 2 main categories:

Uncontrollable parameters: The uncontrollable parameters are mainly unaffected by the human being or human decisions, as the market parameters (the price and performance of the units are available in the time being market) as shown in figure 3, and location parameters as shown in figure 3, 4.

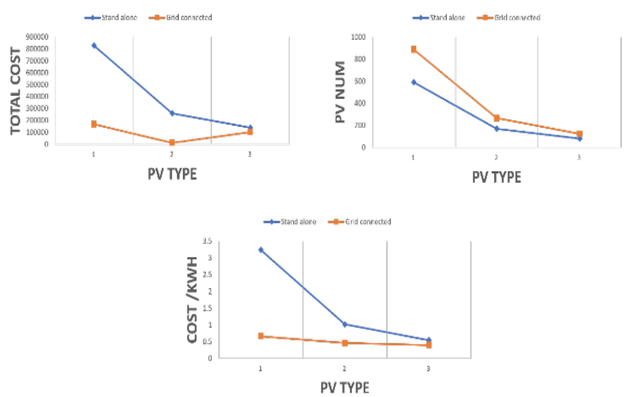

Figure 3. The relation between the cost per kWh total cost and the number of PV with 3 Different types of PV available in the market

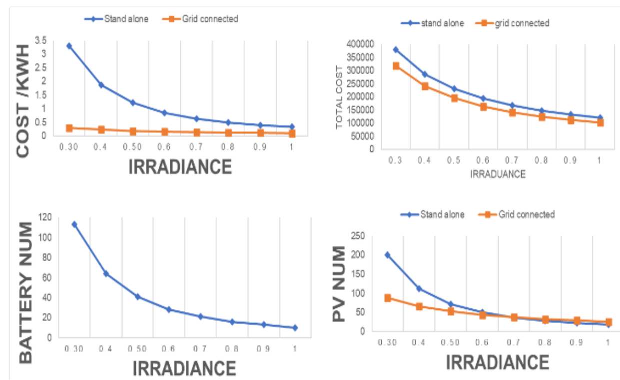

Figure 4. Effect of solar radiation on the size on PV system and cost

Also. The solar radiation varies depending on the location in the earth, as a result of the global horizontal irradiance map as shown in figure 5. As it is clear the UAE region reaches a lot of radiation rather than Portugal as an example

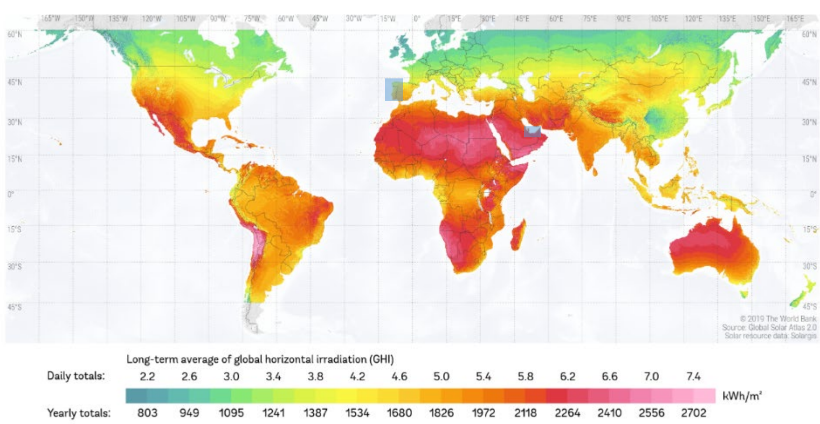

Figure 5. Displays a solar radiation map

Controllable parameters: This parameter have been affected highly with the customer need and human decisions, the first one is the number of saving days (number of consecutive cloudy days) which is for stand-alone system only, as shown in figure 6 the effect of the parameter on the cost.

The saving days is also considered as a location parameter, because the number of saving days to save and store energy will be also taking the reaching of sunbeam too. So, for UAE the worst scenario of consecutive cloudy days will not exceed 2 days, unless in Germany the cloudy days could be more than 3 days, to the aim is to make the home powered within the cloudy days too in safe way.

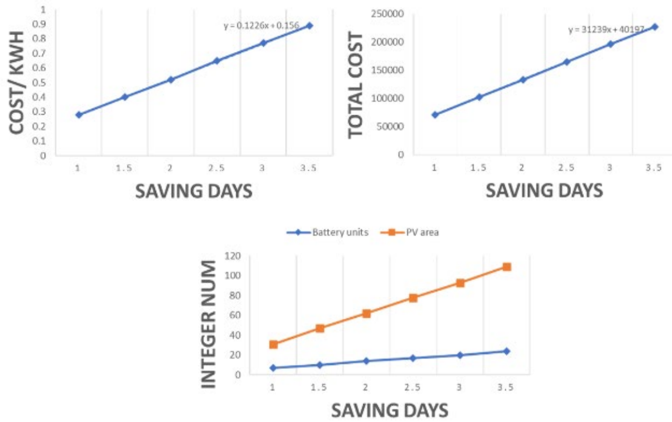

Figure 6. Effect of Saving days on the size on PV system and cost

5. Results and Discussion

Since the weather may significantly affect the production of solar energy, a system should be built with the minimum number of saving days, which in the United Arab Emirates is one day. For instance, cloudy or overcast conditions might lower the quantity of sunshine that reaches solar panels, which will diminish the amount of power produced as shown in figure 7. Similar to heavy snowfall, the panels may become shaded and lose some of their efficiency. The generation of solar energy can increase, though, in clear, bright conditions. Temperatures can have an impact since hot temperatures can reduce the effectiveness of solar panels

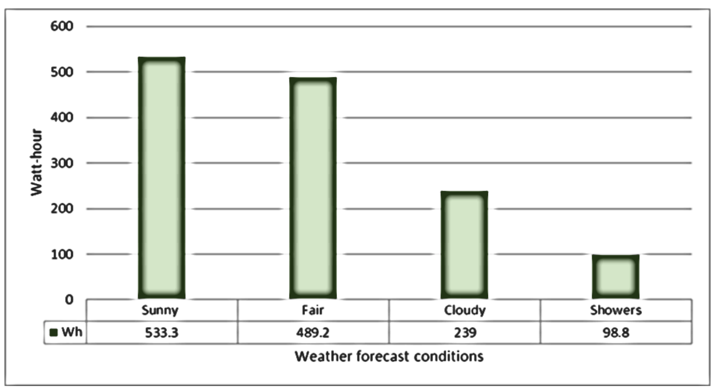

Figure 7. Relation between watt-hour and weather forecast conditions.

Additionally, geography is important for the efficiency of solar energy since regions with more sunlight and less cloud cover are often better suited for producing solar energy than regions with less sunshine and more clouds. This is the reason why deserts, tropical regions, and some Mediterranean nations are more suited for the production of solar energy as shown in figure 7.

To create electricity, the weather thus plays a crucial part. However, the system must be built once, and it will be according to the average of each parameter, so pick the brand of each piece of equipment and be aware of where it will be used. Following the adjustment of every parameter and the implementation of a 1-day energy saving measure, the energy usage will be monitored daily. If there are any changes, the system will act to halt unneeded loads according to priority.
Energy management systems will be used to monitor, manage, and take action on energy.

All of those will be user friendly by using the SolarCast application.

1. **Stand alone system**: as we can't conclude the solar energy if it will be conducted by a standalone system that while controlling the saving days that means we will lead to decrease the total cost of the system.
2. **Grid connected system**: for the grid connected system the way to control and decrease the cost is to control the tariff coming from the government itself, and that it will be depends on each country and depends on many other parameters.

So, we will focus on the solar systems the stand alone only.

5.1 The SolarCast application:

Using App Inventor MIT, a thorough system will be created that includes calculations for the required quantity of PV panels and batteries as well as an estimation of the total system expenses. The software calculates the location and load requirements to get the estimated number of PV panels and batteries needed. The system as a whole will then be given a cost estimate. Users will also be able to choose a budget, Therefore, the program will dynamically modify the system's architecture to satisfy the budgetary restrictions. The application we developed can be described as follows: Upon launching the application, the main screen, depicted in Figure 8, is displayed. The first and second options available on this screen allow users to access the load schedule (Figure 9) and determine the appropriate system size (Figure 10). To provide accurate information, users are prompted to input the irradiance value specific to their location. This value is then utilized to generate a weather forecast for the following day, as shown in Figure 11. By comparing the estimated energy consumption of a home with the predicted weather conditions, as illustrated in Figure 12, any discrepancies can be identified, enabling the determination of the actual energy required. Then the last screen is to find the plan to, which load will be switched off, as shown in Figure 13.

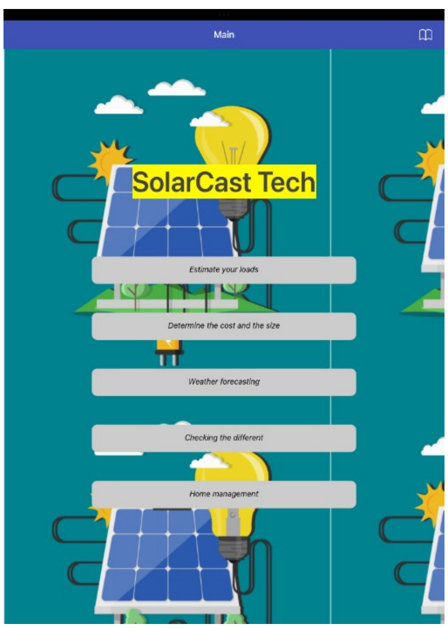

Figure 8. the main screen

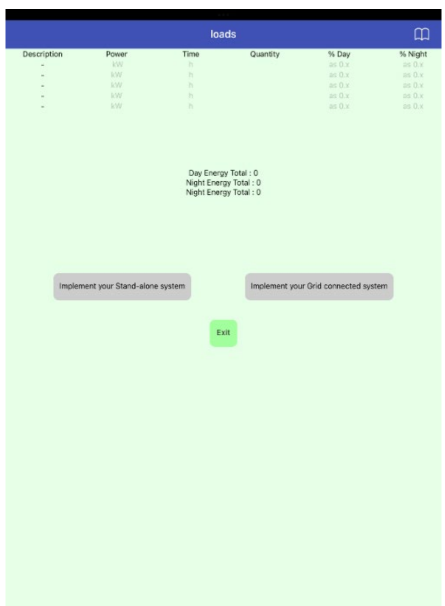

Figure 9. the load schedule

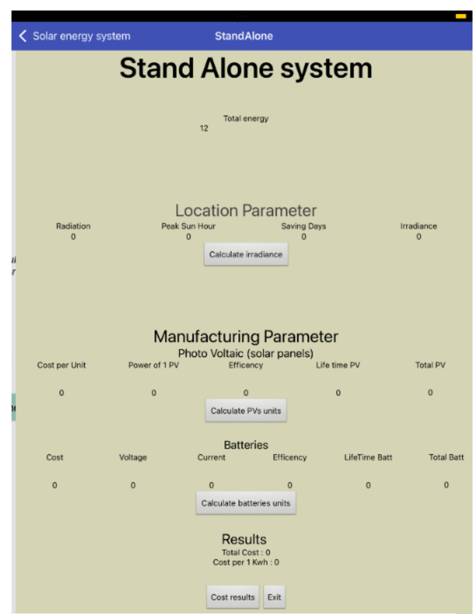

Figure 10. Standalone system

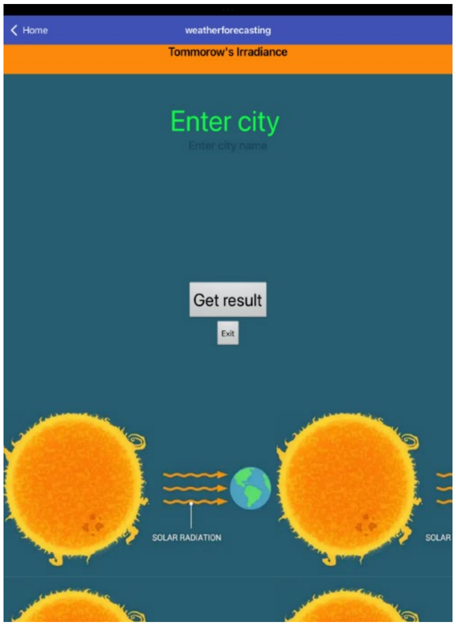

Figure 11. The weather forecasting

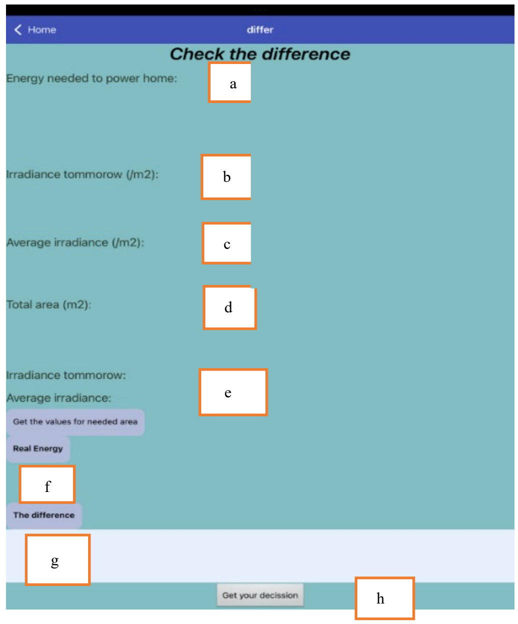

Figure 12. Checking the difference screen

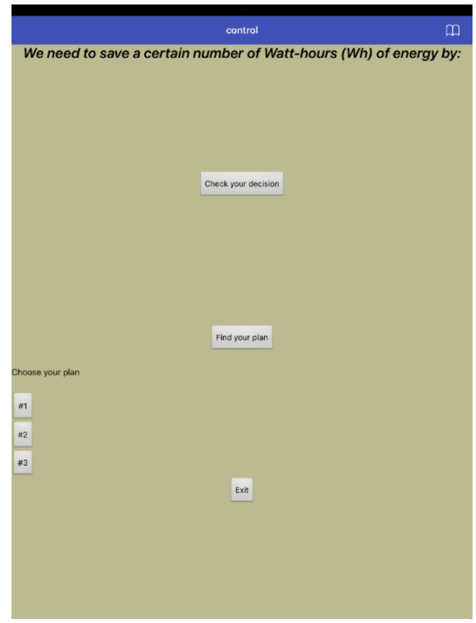

Figure 13. controlled loads are determined.

- [a, b, c, d]: Will be added automatically from previous SCREENS (load, weather forecasting, estimate the size of the system).
- [e]: to find the value of our needed area.
- [f]: Press the button to evaluate the real energy that will be produced.
- [g]: Press the button to evaluate the difference between the real energy with needed one.
- [h]: Press the button to go to the next screen that aims to get your plan decisions.

Flowchart of how the application works has been illustrated by figure 14.

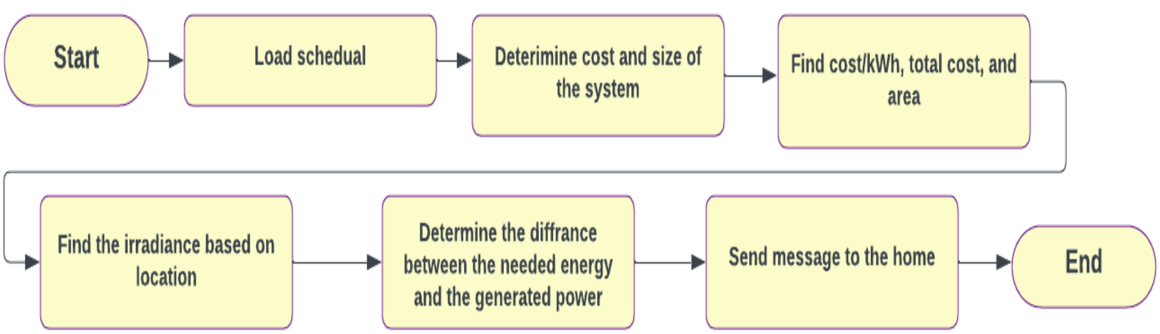

Figure 14. Flowchart of the SolarCast application.

5.2. Weather forecasting:

As a main part of the app is to monitor the condition of the weather for the next day as is the duty of the 4th screen. By detecting the next day's energy condition, customers can use an Energy Management System (EMS) to plan their

energy consumption accordingly. It is advisable to turn off appliances when not in use to reduce energy consumption and lower electricity bills. Appliances known as "vampire power consumers" still consume significant amounts of energy even when turned off, so unplugging them is the most efficient way to stop energy consumption. High-energy consuming appliances include refrigerators, air conditioners, televisions, home entertainment systems, laundry and dishwashers, computers, and chargers.
Global satellite data has been utilized for weather forecasting to measure solar irradiance as taken from open data information. The fluctuation of irradiance in Wh/m2 for the upcoming 15 days (starting from May 7th till May 21st) in Fujairah city is depicted in Figure 15

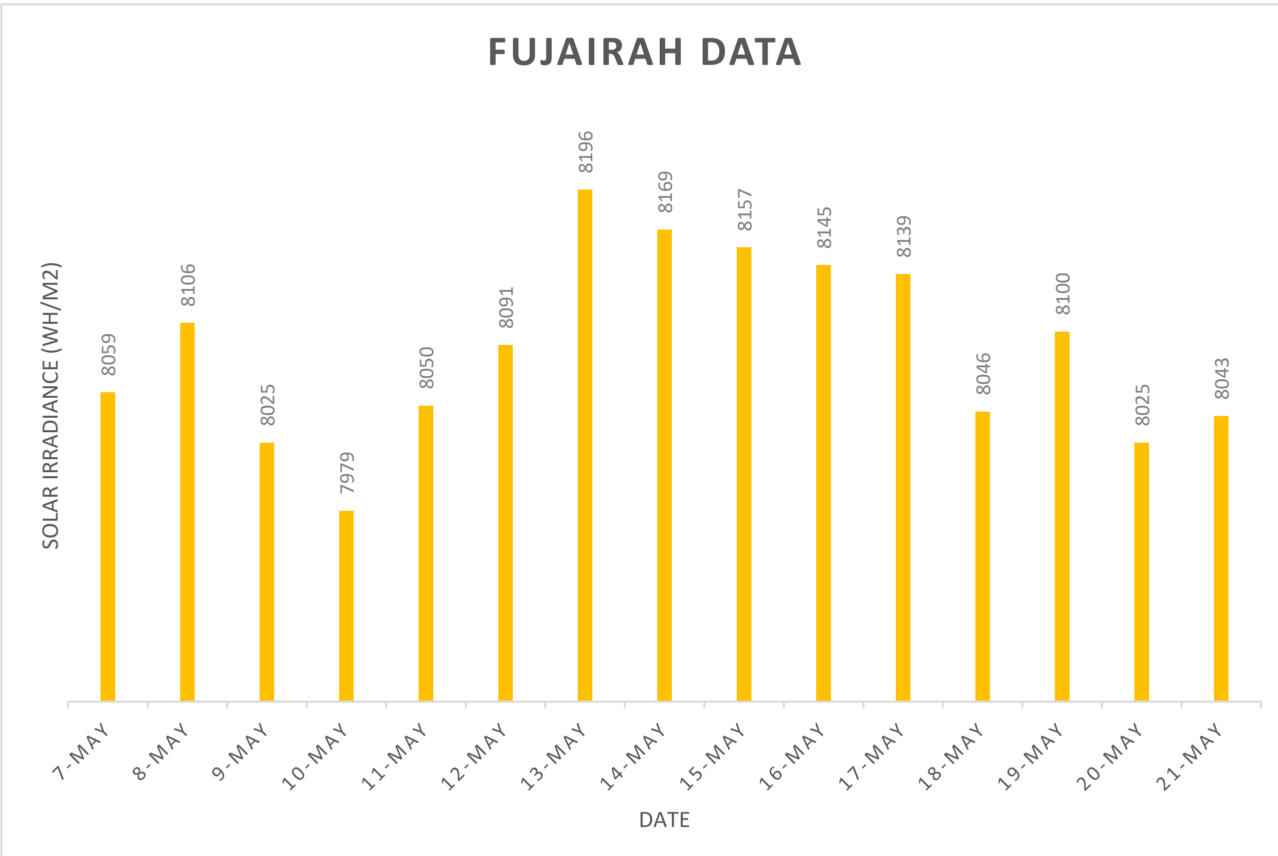

Figure 15. Fluctuating of irradiance in Wh/m2 for 15 days.

As a result of the final massage by the final screen of the application, the controlling message will be send to the home (controlling unit) to isolate the load we needed to turn it off, or to make plan to be worked for though another day with better condition.

The saving days have a significant impact on the cost of the system. For example, in the UAE, taking 2 days will result in a cost per KWh of 0.43 AED; however, if the system could be implemented in 1 saving day, the cost would drop to 0.23 AED, a 46.5% reduction. From Table 2's tabulation of the entire reduction percentages with respect to 1 day, it is clear that cutting the saving days will result in a significant cost reduction.

Table 2. relations between saving days and the cost/KWh with the percentage of reduction

Saving days	COST / KWh	Percentage of reduction
1	0.23	0%
1.5	0.33	30.3%
2	0.43	46.5%
2.5	0.52	55.7%
3	0.62	62.9%
3.5	0.72	68.1%

5.4 Proposed Improvements

The technology may examine a customer's patterns of energy consumption and make recommendations for how to use energy more efficiently. Customers will be able to make cost-effective decisions about their energy use thanks to this. Customers may also set energy usage targets and monitor their progress towards attaining them with the use of individual accounts. For individuals trying to cut their energy costs or their carbon footprint, this function may be helpful. Customers may maintain motivation and progress toward their goals by defining targets and keeping an eye on their energy use.

The system works by receiving data from sensors and analyzing it to determine the optimal energy usage plan. Based on this plan, the system sends commands to the loads, either to switch them on or off or to adjust their usage according to the demand. The system can also prioritize loads based on their importance, ensuring that critical loads are always supplied with power.

6. Conclusion

In order to choose the most efficient system, environmental considerations must be considered while installing a smart solar energy system. Both the Stand-alone and the Grid-connected systems are effective, but they are reliant on factors like location, manufacturing parameters, geographic characteristics, unique parameters, and weather predictions. Grid-connected systems do not require storage devices, whereas stand-alone systems must; nonetheless, power tariffs might affect the cost of system installation. Weather predictions may significantly reduce energy use regardless of the solution chosen by increasing user awareness or enabling automation through energy management systems.

To improve energy efficiency, it is crucial to thoroughly consider the system options and pick the one that is most appropriate for environmental circumstances. Delaying the control plan is crucial because it enables better energy planning and coordination. For instance, the system may postpone the control plan for some loads until a later period when the demand is lower if it detects a high energy demand at a particular time of day. As a result, the system won't be overworked, and energy will be utilized effectively.

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Biography

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