Solar Islands

“The technology promises a zero-shadowing effect and at least 30% less land space than typically required for CSP plants” – T. Meresse, CEO

For
Professor D.L. Prescott
Associate Professor
American University of Sharjah

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English for Engineering Students (ENG 207)

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Dear Dr. Prescott,

Please find our multi-disciplinary engineering project report attached entitled *Solar Islands*. The project focuses on a new technique in generating solar energy, which could serve as an alternative to the excessive use of fossil fuels.

The report combines work from mechanical, electrical, computer and chemical engineering disciplines. We used scientific databases in addition to the advice of an expert informant and senior design colleagues to for our topic investigation. The mechanical engineering discipline focuses on thermodynamic relations of the solar island mechanical system and provides appropriate materials to be used. Electrical engineering is involved in defining the suitable instruments' dynamic characteristics as well as power generation and transmission. The computer engineering is responsible for maintaining the control system, which includes a large sensor network for taking different measurements such as temperature and humidity. The chemical engineering perspective aims to use chemicals such as molten salt to store energy and enable power supply at night. A detailed analysis of the solution is included to determine to which extent it is efficient.

We show our greatest gratitude to Dr. David Prescott for guiding us in this project. We would also like to thank Mrs. Alanna Ross – Associate Librarian at AUS - for dedicating a tutorial session that introduced us to reliable engineering databases such as IEEE and ProQuest Science. Our special thanks go to Dr. Andreas Poulikas, from the Mechanical Engineering Department, who has helped us in understanding various power generation cycles.

We hope that our report fulfills the criteria of submitting a multi-disciplinary engineering project. If you have any further questions concerning our project or report, please contact Yaseen Al-Tajer at b00039778@aus.edu.

Yours sincerely,

**Solar Island Team**

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Executive Summary

The increasing rate of growth in the industrial world has led to an intense demand for energy production. The current dependency on non-renewable fossil fuels is an unsustainable solution. The objective of this report is to examine alternative ways to utilize renewable solar energy solutions.

The main methodology for this project was secondary research, which involved document searching and studying renewable energy related theory from academic books that involved all of our four disciplines: mechanical, electrical, computer and chemical engineering. Primary research was also carried out in the form of interviews with professors who have professional knowledge in the solar energy field and who have contributed to its research.

Solar Islands are proposed as a solution to the current situation of energy resources. They are rotating islands that are aligned with the sun’s movement. Also, solar islands occupy less space than the other solar power plants in addition to being more efficient in energy harvesting. The project is a contribution of mechanical, chemical, electrical and computer engineering disciplines. The mechanical engineering is necessary for the mechanical aspects of the island’s structure. Storing and transforming energy is a chemical engineering field. Moreover, the electrical engineering discipline focuses on optimizing and operating the system control section of the project. Finally, computer engineering is needed for control as well as monitoring the sensor networks of solar islands.
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**Glossary**

**GREENHOUSE GASES** are atmospheric gases that trap heat and various other radiations from the Earth, causing the greenhouse effect. Examples of greenhouse gases are carbon dioxide, methane, nitrous oxides and water vapor.

**SOLAR ISLANDS** are circular structures floating both offshore and onshore, with solar panels placed on top of them, created for the purpose of power generation.

**CONCENTRATED SOLAR POWER (CSP)** is a system which optimizes the heat of the sun’s rays by concentrating them on a certain working fluid using a set of solar reflectors and concentrators.

**SHADOWING EFFECT** is the effect that several structures have on each other upon being placed close to each other. If part of an object is placed between the sunrays and another object, the further structure ends up being in the shadow of the one in front of it.

**PAYBACK PERIOD** is the amount of time required for an investment to generate cash flows sufficient to recover its initial cost.

**PATTERNING** is a process used in micro-fabrication to pattern parts of a thin film or the bulk of a substrate. It uses light to transfer a geometric pattern from a photomask to a light-sensitive chemical called a photoresist.

**AZIMUTH TRACKING** is a technique that orients photovoltaic panels, reflectors, lenses or other optical devices towards the sun. This technique is used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel which consequently increases the amount of energy produced.

**EXTRA FLAT CONCENTRATORS (EFC)** is an array of mirror blades that is positioned in such a way that maximum amount of sunrays can be concentrated on the solar thermal absorber tube.
PHOTOVOLTAIC is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors.

YOUNG’S MODULUS is a measure of the stiffness of an elastic material and is a quantity used to characterize materials.
1. Introduction

As global demand for energy is increasing due to the vibrant industrial growth, the supply of fossil fuels, which are currently the main source of power, is becoming increasingly expensive, rare and therefore unsustainable. Not only are these non-renewable energy sources expected to run out by 90 years [1], but also they are also harmful to the environment. The constant emissions of green house gases from current power plants have been proven to cause significant damage to the Ozone layer, as well as contribute to the pollution of the atmosphere of the Earth. Some of the forms in which these green house gases have affected the atmosphere are through global warming, melting of the poles, which causes a rise in sea level, acid rain and significant climate change all around the Earth.

As a result, it is very important that countries all over the world start adopting renewable energy technologies, which would reduce the demand on fossil fuels, and thereby contribute to reducing the negative effects they are having on the environment. In addition, such an approach would secure a long-term solution to the finiteness and scarcity of the current energy sources used.

One of the main renewable power generation solutions currently under investigation is solar energy. Solar energy has proven to be a promising solution to many power-related problems, as many countries –amongst them is the United Arab Emirates- are subjected to heavy exposure to the sun almost year round. This provides a chance to utilize this constant exposure to the sun and use it in our favor by making use of this sunlight. However, even though solar energy is a promising technology, which could help solve many problems, it is still an extremely young technology, and we face many problems and difficulties with utilizing and optimizing it. Therefore, extensive research still needs to be carried out in order to investigate the different options and techniques through which sunlight can be utilized.

This project report is an attempt to investigate and further clarify how a newly developed solar energy harvesting technique, solar islands, can possibly provide a highly-efficient and convenient solution to the many problems we face with solar power retrieval today.

In this project we will attempt to answer the following question: Which techniques can be used to increase the efficiency of solar islands during day and night?

The relatively low start-up cost of fossil fuel-fired power plants has made them the main means of power generation for almost all industries over the years. However, it is becoming clear that the adverse effects such an approach is having on the environment are creating an unsustainability, which is going to ultimately destroy the planet. According to Dr. Andreas
Poullikas, a professor at the American University of Sharjah, whose area of expertise focuses on concentrated solar power plants (CSPs), these combined power plants provide an efficiency ranging between 30-55% [2], and provide diurnal power for industries and residential areas due to the constant firing of fossil fuels. Therefore, it was our main goal in this report to investigate a solar island’s ability to provide power both diurnally and at a relatively high or competitive efficiency to current solar power retrieval techniques.

2. Problems

The main objective of this project is to address techniques that would allow us to increase the efficiency of solar energy harvesting during the diurnal cycle, and to tackle the challenges facing the conventional methods of solar panels. This will help generate feasible, practical and low cost solutions. There are several disadvantages in the conventional methods of solar energy harvesting that we will discuss in this section of the report.

2.1. Size

One of the major drawbacks in the design of solar panels is that they require large spaces of empty land and constant exposure to sunlight. This is because solar energy harvesting is directly proportional to the total area of exposure to the sun. Consequently, the larger the size of the solar panels, the higher the power produced. Large solar panels are not practical or efficient when used at rooftops of buildings, since they need an immensely large roof surface area to be accommodated. Although, some buildings have already installed solar panels, these conventional solar panels suffer from the shadowing effect. The shadowing effect is generally caused when a small part of the solar panels is being covered by any surrounding objects, clouds or nearby solar panels. Cells within a panel are normally wired in series; therefore, shaded cells will affect the current flow of the whole panel, leading to lower energy production [3].

Due to the need of large space, most proposed practical locations for recent solar panel incorporated projects were in the seas, deserts or vast open spaces. As a result, environmentalists’ concerns were increased, because very large solar panels might endanger living creatures or even cause them to change their habitat as well as damage the natural beauty of an area. According to environmental researchers, “Many of today’s CSP technologies require a large land area to reduce shadowing – an effect that is never totally
eliminated. Indeed, solar energy efficiency can be measured by the quantity of energy produced per square meter of land, and adding more land leads to more construction and cabling costs” [4]. Therefore, solar power plants do indeed require large spaces in order to be operated efficiently, and it is clear why this can raise the concerns of environmentalists.

Moreover, some companies adopted different topologies in harvesting solar energy such the two-axis tracking of solar towers and dishes, which also consequently use large land areas and to maximize the energy production per square meter.

2.2. Costs

2.2.1. Investments

Another major con of using conventional solar panels is that there are not a lot of investors in the field. Investment in solar energy requires relatively large amounts of capital and intensive research compared to conventional methods used to generate energy such as fossil fuels. Also, it take a long time to go through the phases of project development and the payback period is relatively much longer than in other power retrieval techniques, which can be a perceived as a risk for investors to put their money in such an industry. Storey (V.P at Zion’s Bank) states, "The general problem with solar panels is that their payback period varies greatly, easily ranging from 10 to 20 years. Thus, economic incentives have been provided to spur installation of solar panel systems and stimulate the market for solar panel products” [5]. Therefore, it is clear why investors are not easily attracted to solar power related projects, and this is one of the main reasons why this area has not had a fair share of research and development yet compared to the current alternative power generation solutions.

2.2.2. Production expenses

Solar panels are based on advanced technologies, which include several complicated components and devices. The complexity involved in manufacturing such panels means they are costly to make, and therefore costly to buy. In addition, the core material that is used in solar panels is silicon, which is similarly extremely expensive to create and manufacture. It takes a large amount of energy to purify silicon, and using it to produce solar cells. Thus, all these factors contribute to increasing the overall cost of manufacturing and/or buying solar panels. Interestingly, although the computer industries have managed to reduce the prices of silicon devices through patterning, solar panel manufacturers do not have that advantage yet.
Hugh Hillhouse, a professor of chemical engineering at the University of Washington, says, “The semiconductor industry makes minutely patterned silicon. You would have to look at it under an electron microscope to see the intricate structure. Their advancements have been about how to design and fabricate that intricate structure cheaply. And the solar cell, which is completely not intricate, is simply a few layers of semiconductor. It changes the economics dramatically since the manufacturing cost is more closely tied to the cost of the material, not the patterning” [6]. Here Hugh basically states that manufacturers have to worry about the cost of the materials from which the solar panels are made, rather than the lower cost of patterning, which has not been implemented in solar panels yet.

2.2.3. Utilization costs

Moreover, the Heritage Foundation calculations and U.S. Energy Information Administration have carried out empirical statistics on the county’s households’ electric bills. They stated that using photovoltaic energy systems have quadrupled the households electric bill for a family of four, with respect to the conventional fossil fuel dependant power grid. The comparatively high cost of solar cells is demonstrated in the graph below:

![Average Electricity Bill for a Family of Four, by Energy Source](image)

**Figure 1:** Heritage Foundation calculations and U.S. Energy Information Administration from Annual Energy Outlook 2010 [7]

As shown in Figure 1, solar thermal power sources cost around $6.05 million, which is over 2.5 times the cost of conventional coal-fired energy systems. This multiplication factor is further increased with photovoltaic technologies, which cost almost 4 times as much as the coal-fired systems.

**Solar Islands**
2.2.4. Transmission costs

After solar energy harvesting and the generation of heat within the solar cells, this energy needs to be transmitted to the power stations, which produce electricity. Since solar panels require large space to generate sufficient energy to fulfill the electricity demands in the residential areas, solar panels along with their power stations are located in remote areas, and therefore need very long transmission lines and expensive cables. Consequently, transmission costs accumulate on the total expenditure of the solar panels installation.

2.3. Power efficiency and harvesting duration

Current solar energy retrieval systems do not provide large amounts of energy compared to fossil fuels, due to problems such as not experiencing full or constant sun exposure throughout the day. As shown in Figure 2, the solar panels are at their maximum operating capacity approximately between 11:00 am to 2:00 pm only, when the sun is directly perpendicular to the solar panels. As the sun rises or sets, the sun's orientation alters which causes the total amount of incident rays reflecting on the surface of the solar panels to be less than the optimum amount for operation. As a result, the energy harvesting is not constant and is not always optimized.

Moreover, the angle at which the solar panels is fixed is also of vital importance, therefore solar panels installed on the roofs should be checked regularly to orient them according to the time of the day or the season of the year.

![Average "fixed" solar panel power output](image)

*Figure 2: Average "fixed" solar panel power output [8]*
3. Solutions

It is clear by now that the excessive exploitation of non-renewable energy cannot continue. Yet as discussed in the previous section, there are many problems associated with the use of a renewable energy source like solar energy. As an attempt to overcome these problems, a new type of solar power plants known as a solar island is under research. Solar islands have the potential to solve many problems that decrease the efficiency and feasibility of current solar power retrieval systems.

3.1. Solar Islands

A Solar Island is a circular floating platform that rotates with the direction of the sun using azimuth tracking [4]. The island uses energy-storing material like molten salt so that it can offer diurnal energy supply. There are onshore and offshore versions of the island. In case of a marine solar island, a swimming ring that is made of pipeline tubing forms the platform and hydrodynamic motors are placed every ten meters along the circumference to turn the island accurately (see Figure 3) [9]. The island is not designed to experience big waves, and should rather be installed on calm water [4]. On land, the island can float on a channel that is filled with water [9]. High quality materials must be used to build the channel so that it does not leak water, which would disrupt the structure of the island. As this might seem costly, the fact is that as the size of the island increases, the cost of building the channel becomes negligible compared to the cost of the solar panels [4]. The right part of Figure 3 shows the land version of the island floating over the channel, as described earlier.

Since the cost of solar panels was just brought into the picture, it is important to

![Figure 3: Onshore and offshore versions of solar islands respectively](9)
state that the panels used for solar islands cost less than conventional solar energy systems. Before explaining the reason, a brief summary of solar panel types is necessary. There are three classes of solar panels, which are photovoltaic panels (PV), low temperature solar panels and thermo-solar high temperature panels. The PV panels are known for being efficient only for a small scale, whereas, on a large scale, they are very costly and they do not fully utilize energy since they have issues with energy storage [10]. For warm water supply, low temperature solar panels (collectors) are used, but they are efficient only for domestic and industrial use [9]. The third type of solar panels, which is used for solar islands, is the thermo-solar high temperature panel. Thermo-solar high temperature panels operate within systems known as “concentrated solar power” systems (CSP), and they cost the least among the other types of panels. These panels act as concentrators or reflectors, which reflect the sun’s rays onto a single pipeline, in which the water flows. This pipeline is connected to a larger pipeline along the circumference of the island, which is further described in the evaluation section of the report. The CSP system therefore generates saturated vapor at a temperature of up to 350°C in the pipeline. The saturated water vapor is then transported along the pipeline to a power plant, which uses the heat from the steam to generate electricity. Such a fluid heating technique acts as an effective alternative to the current coal-firing technique used to heat the fluid [9]. The heat concentrating process is further clarified in Figure 5.

Solar Islands use extra flat concentrators (EFC) due to their low cost and small size compared to the other type of concentrators (see Figure 4 & Figure 5). EFC originally have two disadvantages, firstly, they need costly tracking systems to adjust them with the sun. Secondly, they are costly. Since they are flat, they consist of several delicate and fragile
components, which need to be carefully manufactured and strengthened so that natural causes such as wind do not damage them and reduce their efficiency [9]. The wind resistance can be eliminated if all the panels were placed on a very large platform and turn with the platform as a whole, which is exactly the case in solar islands [9]. This will not only deal with the wind issues, but also, since the platform rotates as a whole, the concentrators can follow the azimuth of the sun. The fact that there is a sun tracker placed within the whole island (on which the panels are fixed) eliminates the need to have expensive tracking system on each and every solar panel, which is the case with current solar panel fields [4 & 10].

3.1.1. Power generation

To further describe the power generation process, the procedure starts when the sunrays fall on the solar panels on the top of the membrane. Then, the concentrators will concentrate the solar radiation by a factor of approximately 20, and reflect them to an absorber pipe that contains the pressurized water [6]. Absorbers are mounted 4 m above the solar panels in a coaxial manner as shown in Figure 6.

In the inner pipe of the absorber, the heated water flows until the end of the branch containing the absorber. When water arrives at the end of the branch, it will go back to a central tube and will heat up further until it transforms to saturated steam. The steam will be sent through the pipeline systems mentioned earlier, to the steam turbine that is placed in a power plant near the island. The heat of the steam will then drive the turbine blades, and a generator connected to the turbine will transform the kinetic energy from the turbine blades into electricity.
3.1.2. **Minor Applications**

Small solar islands with a 20-50 m diameter can be placed on large empty rooftops, and can serve as a heating and/or cooling system for any building, since heat absorption is one of the main parts of a refrigeration cycle. According to research, “with heat you can produce coolness (via a chiller) and in some hot countries, such as the UAE, you have many flat roofs, and you can mount a solar island there on a flat roof or in the garden. The greatest thing is that the more sun you have, the more cold the solar island is going to produce, which is what hot sunny countries need for air conditioning” [4]. Therefore, solar islands can be even used in minor applications to help produce useful services such as air conditioning, or even, in possible cases, producing local power for a building block.

The cooling system that is supported by solar islands can additionally be used in mines to reduce the amount of heat produced. Since water pumping is another issue in mines, a solar island is also capable of performing other jobs than merely cooling. Thierry Meresse, CEO and co-owner of Novaton, the company that invented solar islands, claims, “We are currently in discussion with a company in Chile, on multi-purpose solar islands that could provide cooling and perform pumping simultaneously. Chile is a great country for this, especially in the Atacama Desert, where they are lots of mines and much direct irradiance” [4].
4. Evaluation

It is essential to have solutions for every problem, however, it is even more important to have a good evaluation for these solutions. Following the solutions proposed earlier, our team carried out several evaluations of the solutions regarding solar islands. The details of our evaluated solutions were split into several sections as follows:

4.1. Physical and Safety Components

4.1.1. General Structure

A solar island is consisted of several components that work together to operate and support the whole solar power retrieval system. As shown in Figure 7, the island consists of a circular outer ring pipe made of low-density steel. The low density of steel allows it to float easily on a circular water trench, which extends along the circumference of the island. The water trench is made from a high quality concrete membrane, which similarly extends along the circumference of the island. As shown in the cross section of the island [Figure 7], the concrete layer is curved from the top, acting as the trench for the water to sit on. This concrete layer is used only in on-shore islands, to act as both a water trench for the steel pipe to float on, as well as a supporting base for the whole structure. On the other hand, the steel pipe in offshore islands simply floats on the seawater, without a need for any concrete support. The main membrane, on which the solar panels are placed, lies on top of the concrete base, and is similarly made of low-density steel, to minimize its weight. As shown in Figure 7, the concrete base only needs to be as thick as the steel pipe’s diameter, and it only extends along the circumference of the island. This reduces the total amount of concrete used. This technique can be safely implemented, because the total weight of the membrane and the steel pipe are reduced, due to the overpressure effect, which will be explained later.

4.1.2. General Dimensions and Material Properties

The diameter of the membrane of the solar island is ranges between 20 to 200 m in length [4]. The outer steel ring around the membrane is placed along the circumference, and the dimensions of which (diameter, thickness and height) are proportional to the overall size of the solar island, which varies according to the application. Having the right dimensions is equivalently important to choosing the right material. It is also very essential to take into consideration the mechanical properties of the materials used, because these properties are
extremely important for both safety and efficiency. **Young’s modulus** or the modulus of elasticity describes the stiffness of the material and how readily the material deforms when an applied force is subjected to it. The modulus of elasticity for high quality concrete is $30 \times 10^9$ N/m$^2$ [11], which is sufficiently high compared to other types of materials. High quality concrete prevents leakage of the water from the circular trench, and it significantly reduces the chances of failure of the supports. The modulus of elasticity for structural steel is about $200 \times 10^9$ N/m$^2$, which is extremely large compared to other metals, therefore, it difficult for steel to deform because the larger the modulus is, the smaller the deformation will be [11]. The rigidity modulus is the coefficient of elasticity for shear forces that relates shear stress to shear strain. It determines how elastic the material is if it was sheared or in other words, subjected to parallel forces from opposite sides [12]. The modulus of rigidity for concrete is 3 million psi, while for steel is about 12 million psi [13], both of which are large enough moduli, contributing to a safer and more efficient structure that is less prone to failure.

### 4.1.3. The Overpressure Effect

Most mechanical structures rely on a base at the bottom that supports the whole structure, giving it strength and stability. Installing large amounts of the base material of a structure could prove to be expensive, as the material usually needs to be of high quality in order for the structure to be able to withstand any external forces such as wind. Solar islands provide a solution to the high cost of material for the base structure, through the overpressure effect. As shown in Figure 7, there is a compartment below the island where the air is completely trapped from the outside atmosphere. The air cushion trapped below the membrane eliminates the need of heavy mechanical constructions to support the island [4]. This air that is trapped is pressurized using air pumps, increasing the pressure of the air by less than 1% of the atmospheric pressure, which is 101.325 kPa [4]. Therefore the pressure of the trapped air is almost equivalent to 102.34 kPa. Since this pressure inside the base of the island is higher than the atmospheric air pressure, this leads to the air inside to exert a force from the inside of the membrane, higher than the force exerted by the atmospheric pressure on the outside. Consequently, the resultant pressure pushing against the membrane from the bottom results in a resultant vertical force, which pushes the membrane upwards. As a result, this extra upward force created by the pressurized air, helps reduce the downward force caused by the weight of the structure. The overpressure below the thin membrane is thereby capable of supporting huge distributed loads by exerting a sufficient vertical force, which is
equivalent to the weight of the membrane and the solar panels fixed on top of it without the need of any lateral forces [10]. To further clarify the magnitude of the force created by the minimal overpressure created, studies showed that one tenth of an atmosphere of overpressure exerts a vertical force which is equivalent to 100 grams per square centimeter [10]. This force corresponds to one ton per square meter; therefore, the overpressure is sufficiently high to easily lift the membrane with the solar panels on top of it [10]. Since there is less weight acting on the structure supporting the island, this eliminates the need of heavy mechanical constructions below the island, which in turn, significantly reduces the cost of civil infrastructure, which was one of the main problems with on-shore solar power generation [4].

![Diagram of an on-shore solar island cross section](image)

**Figure 7: Diagram of an on-shore solar island cross section [4]**

### 4.2. Technical aspects

#### 4.2.1. Following the sun technique

The rotation of the island enables following the sun. Following the sun technique eliminates the shadowing effect and reduces the space between the panels; therefore, the total area used is reduced [4]. The reduction of the total area used contributes to solving space and cost problems because less land area leads to less construction and cabling costs. In addition, as mentioned earlier, due to the fact that the island rotates as a whole, the cost of adding several sun tracking systems can be avoided, and this contributes into solving the cost problem.

#### 4.2.2. The rotation of off-shore and on-shore solar islands

The rotation of an offshore solar island is done by electric hydrodynamic motors that are fixed every 10 meters along the island’s circumference [10]. The same principle is applied for an onshore solar island, but in this case, drive wheels are used for the propulsion of the island [10]. Overpressure and temperature that are trapped below the membrane, in

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addition to the level of water in the circular trench, are important for controlling the precision of the island’s rotation [14].

4.2.3. **Eliminating the shadowing effect**

Many concentrated solar panels (CSP) technologies require large spaces of land in order to reduce the shadowing effect [4], which mainly depends on the space between the collectors, their height and the length of the row of panels or collectors [15]. The shadowing effect is a result of the collectors’ arrangement that causes shadows on the adjacent rows of the collectors. Being exposed to less sun rays means there is less heat reflected by the solar panels, which means lower power generation, and this significantly reduces the efficiency of the system [15]. The EFCs used in solar islands, allows the panels to be arranged in such a way that they are always perpendicular to the sunlight. This causes the shadows of each panel to mostly exist vertically underneath the panel itself. This minimizes the shadowing effect on the other panels, and therefore ensures maximum sunlight exposure throughout the day.

Conventional solar power systems tackle the shadowing effect by placing the panels at long distances from each other, to ensure that their shadows do not disrupt sunlight exposure to other panels. However, in solar islands, eliminating the shadowing effect allows for placing the panels extremely close to each other, which contributes to solving the area problem, by reducing the total area by-at least- 30% less than what is typically required for the same amount of energy generated [4]. The panels cover up to 90%-95% of the island’s platform area [9].

As a demonstration of the great power generation potential of solar islands, it was found that an island of a radius of 1.5km, covering an active surface area of 6.4 square kilometers, provides a maximum power of 0.96 Giga Watts, a mean power of 192 Mega Watts and an energy of 1.5 billion kWh per year. This was a large-scale schematic calculation of a solar island, and it corresponds to the energy produced by a small sized nuclear power plant [9].

Using the average The “Following the sun” technique, along with the avoidance of adding sun tracking systems for each panel, both contribute to increasing the efficiency of solar islands by up to 15% more than conventional solar power generation systems [16].
4.3. Molten salt storage technique

Since the sun is available for a limited time each day, solar power generation is usually optimized only during the day. Such a limitation with harvesting duration makes solar power a very unreliable energy source, since a stand-alone solar power plant is not able to provide power during the night. Therefore, many solutions to this problem have been proposed, in order to help allow diurnal power generation. The most prominent solution is the molten salt storage technique, which utilizes the extremely high heat storage capacity of molten salt by using it as a heat storage tool. Several molten salt pipelines are placed in line with the water pipelines, resulting in some of the sunrays to be concentrated on the salt as well as the water. The salt used, which is a mixture of sodium and potassium nitrates, is heated to around 550°C, and since it has a melting point of 220°C (460° F) [17], it easily melts, enabling it to freely flow through the pipeline system to a molten salt tank, where it is stored, which is placed by the power plant. Molten salt maintains its liquid state even above 1000°F, which allows it to be heated and stored, and allows the system to operate at low vapor pressure without the risk of burning [17]. When energy is needed, the molten salt is piped into a heat exchanger in the power plant, where the heat is transferred from the molten salt to the water (the working fluid), generating high temperature steam, which is then used to produce electricity at the turbine. Therefore, the salt collects the energy that solar panels gather from the sun, and its high heat capacity is utilized to help produce electricity at night. Finally, the cooled molten salt is returned to the cold storage and the thermal cycle repeats itself [19]. The basic principle of the molten salt heat storage technique is shown below in Figure 8. Although this schematic is for a solar tower, the procedure is almost identical.

![Figure 8: Molten salt for thermal energy storage [20].](Image)
4.4. The solar island is a promising technology

Solar energy is the most promising source of energy since it has a daily radiation of 6.5 kWh/m², and it is a long-term source of energy for mankind. Solar islands provide a unique way to reach the goal of harvesting sun’s energy in large quantities at lower costs. They are moderately priced and produce clean energy on a very large scale, therefore, solar islands can be considered to be a promising technology in the future [14]. Solar islands protect the environment and health because it is an environment-friendly technology with no CO₂ emissions [21]. Figure 9 shown below introduces a cost per kWh comparison between solar islands and other conventional power generation systems. It is obvious from the graph that solar islands are extremely cost competitive compared to other systems [9]. To sum up all the points explained earlier, a solar island has less civil infrastructure cost since overpressure is used to support the island’s structure. The rotation of the island eliminates the shadowing effect and reduces the space between panels; therefore it contributes into solving the space problem. In addition, adding a sun tracking system to each receiver can be eliminated; hence, it contributes to solving the cost problem. Moreover, molten salt is used for thermal energy storage during day and night, which extends operating hours and increases the efficiency.

The full project has not been implemented yet; however, load tests and rotation tests have been successfully completed in a solar island schematic in Ras Al Khaimah, United Arab Emirates. In addition, there are three solar islands located on a lake in Switzerland called “Neuchâtel”. This is evidence that companies have indeed started to invest in solar island technologies, and are foreseeing their great power generation potential for the upcoming future.

![Figure 9: Cost comparison between different sources of energy](image-url)
5. Recommendations

After researching techniques for increasing the efficiency of energy harvesting using solar energy, we recommend the implementation of both onshore and offshore solar islands, to ensure optimum generation of electricity. We also recommend that the solar islands utilize the Azimuth sun tracking system located under the pump that surrounds all the panels instead of placing a sun tracking system on each panel on the island. Moreover, we recommend that molten salt technique is taken into consideration in future projects and scientific research to examine how the energy storage capacity of the molten salt can be increased. These solutions were proposed after deep analysis and intense research that has led us to conclude that solar islands are the smart, most efficient solution to many of the problems we face with solar power generation today.

However, for all of the above to be accomplished, we most importantly advise that governments take the initiative to provide subsidies and incentives for companies and investors, to encourage investing and contributing to the research and implementation of such a promising technology, and to encourage new innovative ideas in optimizing the energy harvesting in solar islands.
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