Global Scientific JOURNALS

GSJ: Volume 12, Issue 6, June 2024, Online: ISSN 2320-9186
www.globalscientificjournal.com

NAZARBAYEV INTELLECTUAL SCHOOL OF CHEMICAL AND BIOLOGICAL DIRECTION UST-KAMENOGORSK

Topic: **Investigation of Methods to Increase the Efficiency of Solar Panels as an Independent Energy Source and in Water Purification Systems**

Field: Technical Sciences- Energy

Author: Oralbekova Kamila
Supervisor: Physics Teacher, Master of Natural Sciences Muratbekov B.M.

Ust-Kamenogorsk 2024

CONTENT:

ABSTRACT

Lack of energy and clean water are two key problems of global sustainable development. Almost half of the total water intake in the world is consumed by power plants, while desalination consumes a lot of electricity. Obtaining energy without more CO2 emissions and harm to the environment has become possible by solar energy, which has demonstrated enormous potential to meet future global energy needs, given its abundance and availability.

Solar photovoltaic installations are widely used in the field of renewable energy production at industrial and commercial facilities.

Hypothesis: Placing on the water and using the Peltier element can increase the efficiency of solar panels. The use of a multi-stage membrane distillation structure in solar panels will allow to simultaneously receive electricity and produce clean water.

In this work, the following goal is set: To investigate the effectiveness of placing solar panels on water, the use of a Peltier element, multi-stage membrane distillation for water purification in solar panels. In this work, tests were carried out on the efficiency of the distillation design, the calculation of the volume of pure water output, the percentage of minerals in "purified" water, the energy efficiency of solar panels, the efficiency of the Peltier element and the design of "Floating" solar panels.

Novelty of the work: We have considered methods of reducing the temperature of solar panels and developed a design capable of purifying water under the influence of residual heat from the operation of solar panels, which can be a solution to the problems of shortage of fresh water from arid zones without consuming more electricity.

Results of exploration: **We recommend using the** results of the work when installing solar panels to generate electricity in areas with a large amount of solar radiation and a shortage of fresh, purified water.

INTRODUCTION

Relevance: Solar panels are one of the main components of renewable energy, but many face the problem of excessive heating of solar panels, subsequently reducing efficiency, while residual heat during the operation of solar panels is released into the environment as waste. In our project, we consider methods of reducing the temperature of solar panels and using heat as a resource for distillation water purification, which makes it possible to generate electricity from solar panels while simultaneously purifying water from contaminants.

Hypothesis: The use of the Peltier element and the "Floating" solar panel design will reduce the heating percentage, and the multi-stage membrane distillation structure in solar panels will allow simultaneous electricity generation and clean water production.

Research Objectives: To investigate methods of cooling solar panels, the possibilities and efficiency of the multi-stage membrane distillation structure in solar panels for water purification.

To achieve the research objective, the following research tasks were set:

- Determine the efficiency of temperature reduction in solar panels using the Peltier element.
- Assess the effectiveness of floating panels for cooling the design.
- Use a membrane distillation structure under the influence of residual heat from solar panels to purify water.
- Analyze the possibilities and efficiency of the design.

Research Stages and Procedures: Use the Peltier element with solar panels. Determine the temperature difference. Conduct tests on the efficiency of the floating solar panel design. Determine efficiency. Build a multi-stage membrane distillation structure. Calculate the volume of pure water output, the percentage of minerals in purified water.

Applications: Methods for increasing the efficiency of solar panels are in demand and can be used in commercial projects since the problem of excessive heating is observed in all photovoltaic panels. The multi-stage membrane distillation structure can be widely used in arid regions with a large amount of solar radiation and a shortage of purified water, with parallel electricity generation.

Experimental Methodology: The main experimental methods included tests on the efficiency of solar panels, the impact of the surrounding water environment on the temperature of the solar panel; experiments with the Peltier element under 12V LED light using a multimeter, temperature checks with a thermocouple; building a membrane distillation structure, collecting purified water during the experiment using calculations.

Novelty and Degree of Independence: Solar panels often lose efficiency due to strong heating under the influence of excessive solar radiation. We explored methods of reducing the temperature of solar panels using the Peltier element and floating panel design. We developed a multi-stage membrane distillation structure with solar panels to address the problem of freshwater shortage using excess heat from solar panels.

Oralbekova K.A. independently conducted tests on the efficiency of "floating" solar panels, worked with tools for experiments, implementing the Peltier element into the work. Participated in the development of the membrane distillation structure.

Practical Applications of Results: Methods for reducing the temperature of solar panels show good results in practice. The multi-stage membrane distillation structure has the potential to work with solar panels for water desalination in regions with a shortage of purified water. We recommend using the aforementioned in commercial solar panels to increase efficiency.

ANALYTICAL REVIEW

A pressing problem of our century is the pollution of the atmosphere with greenhouse gases through the burning of traditional energy sources such as gas, oil, and coal. Coal is the most common fuel in the world and is used in thermal power plants to generate electricity. With large-scale production, greenhouse gases and chemical elements released in high concentrations have a detrimental effect on human health while leading to global warming. To solve this problem, scientists are developing and implementing alternative energy sources that use water, wind, and sun as the main links in the production of electricity. Using solar radiation as a resource in solar panels is becoming a more widespread trend. Solar panels are photovoltaic converters in a physical sense. Electricity is generated through the semiconductor p-n junction. Photovoltaic semiconductor elements are essentially photodiodes, converting the energy of electromagnetic radiation into electrical energy.

Using solar panels as an energy source is becoming more relevant due to the inexhaustible, free, and clean resource of solar radiation. Approximately $1.2 * 10^5$ TW of solar radiation reaches the Earth's surface, making it possible to use it as the main type of alternative energy [1].

A significant disadvantage of solar panels is their rapid heating, subsequently reducing efficiency. Overheating of silicon photovoltaic panels due to excessive solar radiation and high ambient temperatures is a serious problem, especially in the Middle East and North Africa (MENA) region. In such regions, the temperature of photovoltaic panels can easily rise to 75 °C, corresponding to a decrease in efficiency of about 25% [2].

To reduce the temperature of solar panels, the Peltier effect can be used, on which the Peltier element is based, being a thermoelectric device capable of creating a temperature difference under applied voltage. When voltage is applied, one of the contacts of the Peltier element heats up, while the other cools. When current passes through the contact of such materials, the electron must gain energy to move to another area. When this energy is absorbed, the contact point of the semiconductors cools down [11].

For reducing the temperature of solar panels, the construction of floating solar panels is widely used. Since the module temperature of floating photovoltaics is lower than that of ground-based photovoltaics, the energy production efficiency of floating photovoltaic systems is 11% higher than that of ground-based systems [3]. Photovoltaic systems installed on water are cooled, thus preventing the heating of silicon solar panels. Akbarzadeh and Wadowski developed a hybrid photovoltaic solar system and found that cooling the photovoltaic panel with water increases the output power of solar cells by almost 50%. It was found that using water as a cooling fluid reduces the temperature of solar cells by 8°C and increases the panel efficiency by 3% [4].

Photovoltaic systems can displace food crops and invade arable land, contributing to the ongoing "food vs. fuel" controversy [5]. These related land and food issues may seem insurmountable, but with the help of photovoltaic systems on water bodies, the land shortage problem can be addressed by moving solar panels onto water bodies. Solar panels built on water solve the land shortage problem, which is the most important resource in short supply for agricultural use. Water surfaces can be cheaper than land costs. There are fewer rules and regulations for structures built on water bodies not used for recreation.

Solar panels can be installed on industrial ponds (sand quarries, mines, cooling ponds, etc.) or wastewater treatment ponds. In these cases, full coverage (90-95%) is recommended. For irrigation ponds, reservoirs, a coverage range of 30-60% is a good option. Hydropower station ponds, reservoirs: in this case, artificial ponds equipped with power plants and already connected to the power grid can be very large. Thus, the use of the surface can range from 5-10% (for very large surfaces) to 50-60% (for small to medium-sized surfaces).

The production of clean water is a very energy-intensive and challenging process. Currently, more than 15% of the world's population suffers from a lack of fresh water, and according to United Nations forecasts, by 2025, the water shortage will affect 26% of humanity [7]. On average, 780,000 people die annually due to inadequate water supply and sanitation, and approximately 55 million people suffer from drought, causing economic damage amounting to more than 5 billion USD. Water consumption increases by 1% annually. This rate has been observed since 1980 and is expected to continue until 2050. Besides daily human needs, the demand for water arises in various sectors, including energy production, agriculture, and industry, where it is used in various operations such as cooling and cleaning [10].

Desalination is a significant challenge due to the shortage of drinking water in arid regions and areas with polluted water. Globally, more than 17,000 desalination plants have been built, with 48% located in the Middle East and North Africa. Despite the enormous amount of desalinated water—95 million m3/day—desalination plants are still insufficient to meet drinking water needs [8].

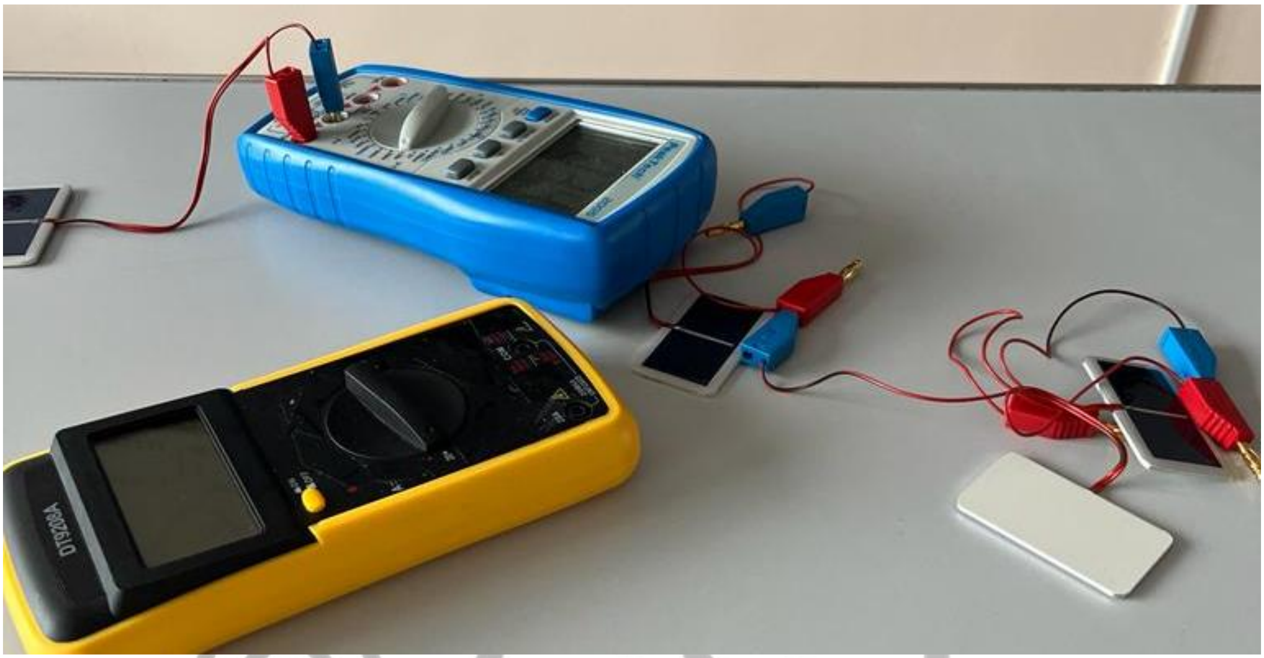
For example, in Arab countries, more than 15% of the total national electricity consumption is used by the freshwater production industry. It has been reported that 1 to 10% of the clean water obtained from seawater desalination using electricity is fed back into the power plant to generate electricity consumed in the desalination process. Solar distillation has recently attracted significant attention and has demonstrated promising potential in various processes aimed at seawater desalination. In a solar cell, 80-90% of the absorbed solar energy is undesirably converted to heat and then released into the surrounding air [6]. The heat released from solar panels can be used for water purification and desalination through the evaporation and condensation of the liquid in the membrane distillation structure.

Membrane distillation construction is a hybrid process that includes both membrane and thermal distillation mechanisms, depending on vapor transport through a microporous membrane that prevents wetting and serves as a barrier for the liquid phase. The membrane pores allow distilled vapor to pass only to the cold side. The driving force is created by the vapor pressure gradient existing between the membrane surfaces. Membrane distillation has various advantages over thermal desalination methods. Firstly, it can operate at lower temperatures. Secondly, it provides a modular-compact system design compared to traditional thermal desalination configurations [7].

By 2025, the global photovoltaic system capacity is expected to increase to 969 GW, requiring approximately 4 billion m2 of land to collect sunlight. Assuming that Membrane Distillation Construction devices with solar panels with three stages of purification will be installed on this land and will operate for 200 days a year with suitable solar irradiation, approximately 4 billion cubic meters of freshwater will be produced. This is equivalent to 10% of the total global drinking water consumption in 2017 [9].

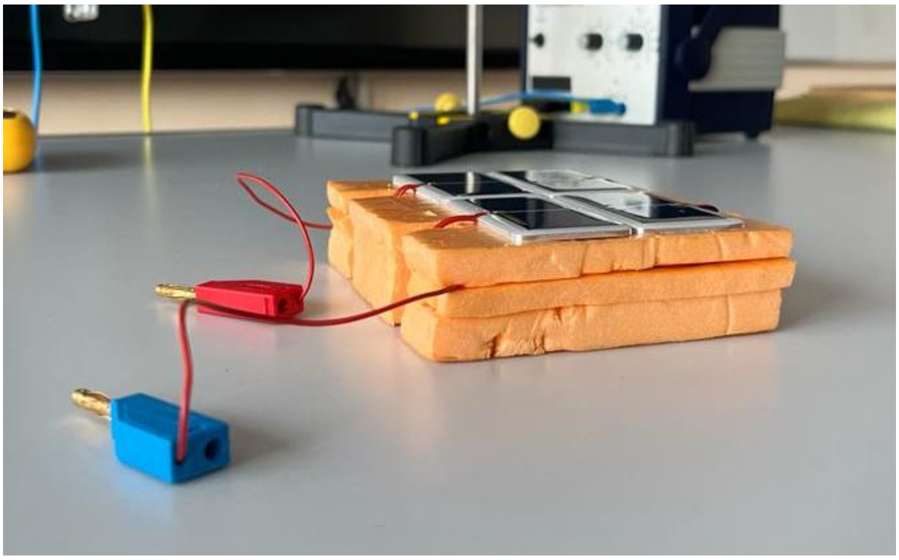
RESEARCH PART

In this study, four photovoltaic panels manufactured by PHYWE with an area of 2*2 cm were used. Three 12V power LEDs and Peltier element TEC1-12706 were also utilized. The base for the floating solar panel construction was made from "Penoplex" (extruded polystyrene foam).



Picture 1- Materials used

1. TESTING THE "FLOATING" SOLAR PANEL DESIGN



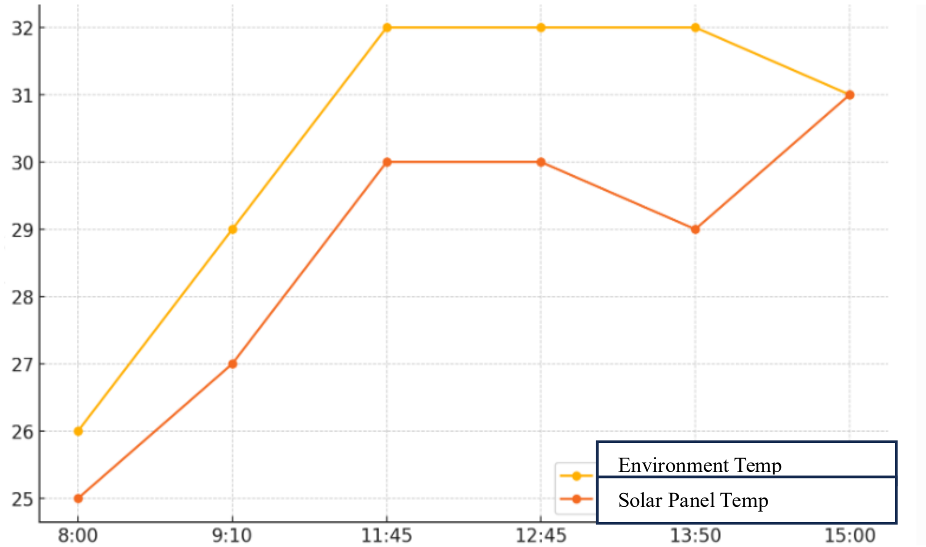
Picture 2 – Floating Panel design

During the experiment, the effectiveness of using solar panels on a floating structure was evaluated. The frame of the structure was made of Penoplex and immersed in water. Four solar panels were connected in series to obtain the total voltage, and the cables connecting the panels were insulated using leftover Penoplex. Two cables were connected to a multimeter to measure the electrical parameters of the system. Under the influence of solar radiation, measurements of the temperature changes of the solar panels were taken, allowing the assessment of the temperature's effect on their efficiency.

The floating panel design was installed on water, enabling data collection on the impact of the aquatic environment on the efficiency of the solar panels. The temperature of the solar panels was measured using a thermocouple. Statistical data were collected comparing the ambient temperature with the temperature of the solar panels at different times of the day. The table built from the measurement results shows data on the temperature changes of the solar panels depending on the intensity of incoming solar radiation.

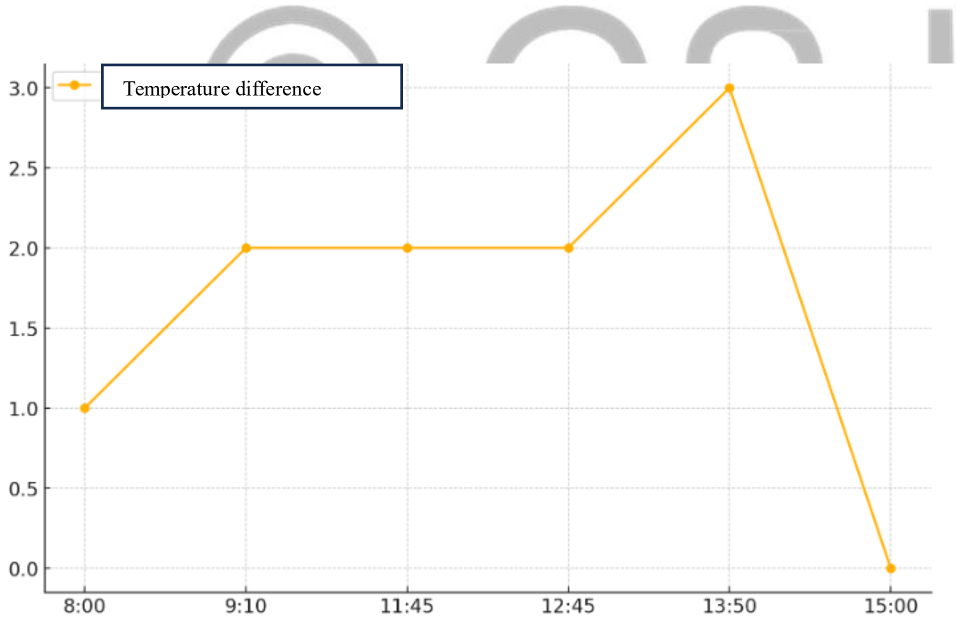
Time/ Hour	Voltage/ V	Environment Temp/ °C	Solar Panel Temp/ °C
8:00	2,00	26	25
9:10	2,11	29	27
11:45	2,21	32	30
12:45	2,20	32	30
13:50	2,18	32	29
15:00	2,20	31	31

Picture 3- Comparison of Ambient Temperature with Solar Panel Temperature at Different Times of the Day.



Picture 4-Environmental and Solar Panel Temperature Changes Throughout the Day

Measurements showed that the average temperature difference between the ambient environment and the solar panels was 1.66°C. This data allows us to conclude the impact of the aquatic environment on the efficiency of the solar panels, as temperature is one of the key factors affecting their efficiency.

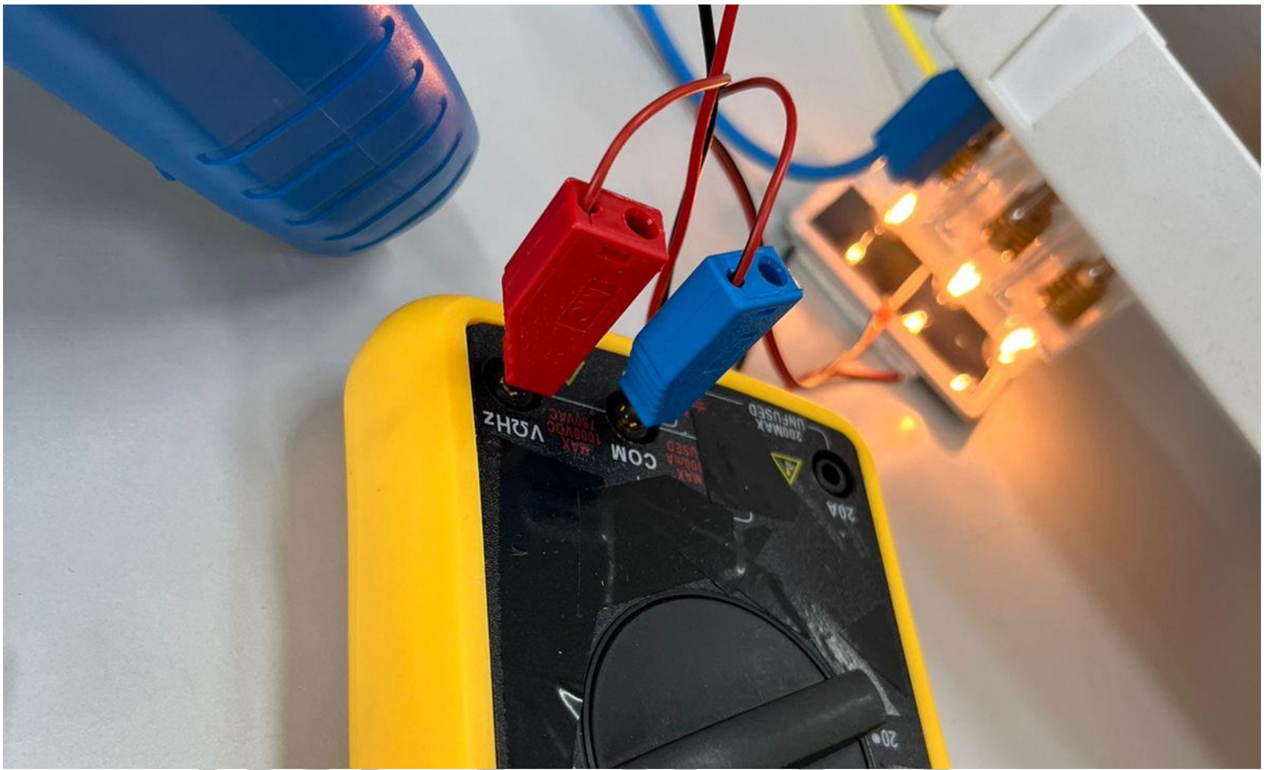


Picture 5- Temperature Difference Between Ambient Environment and Solar Panels: The average temperature difference was 1.66°C.

The conducted tests demonstrate that the use of floating structures can be a promising method for improving the efficiency of solar panels. The lower temperature of the panels, due to contact with water, helps maintain their operability at a higher level compared to ground-based installations.

2. STUDY OF THE EFFICIENCY OF THE PELTIER ELEMENT WITH SOLAR PANELS

The experimental setup for testing under adverse weather conditions included three LEDs connected to a 12V power source. A multimeter was used to measure the parameters of the solar panel, showing a result of 0.51V when the LEDs were illuminated.



Picture 6 – Test Setup for the Peltier Element

The parameters of the solar panel and the Peltier element were measured using a multimeter. The Peltier element was attached to the underside of the solar panel to absorb residual heat as it heated up. The main objective was to convert this heat into electricity by utilizing the temperature difference.

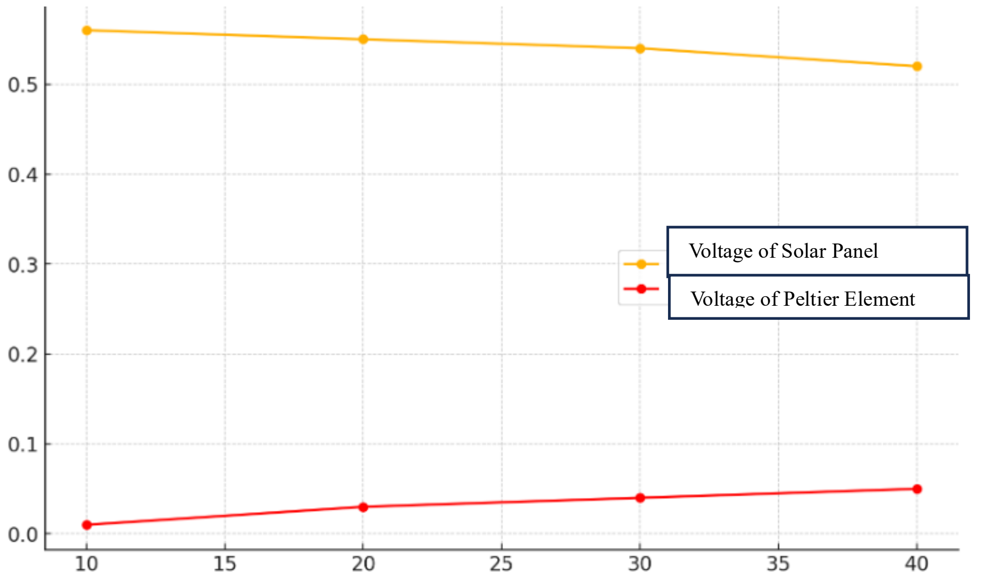
Time/ min	Voltage of Solar Panel/ V	Voltage Peltier Element/ V
10	0,56	0,01
20	0,55	0,03
30	0,54	0,04
40	0,52	0,05

Picture 7- Decrease in Solar Panel Voltage and Increase in Peltier Element Voltage Over the Allotted Time

During the experiment, the solar panel began to heat up, leading to a decrease in its efficiency and a drop in voltage. At the same time, the Peltier element, due to the temperature difference, started generating electricity, resulting in an increase in voltage at its output.

The Peltier element and the solar panel functioned independently of each other. The Peltier element, utilizing the temperature difference, generated electricity, which helped reduce the loss of electrical energy dissipated as heat from the solar panels, thereby increasing the overall efficiency of the system.

Over the course of the 40-minute experiment, the voltage of the solar panel decreased by 7% from its initial value due to the rise in temperature, whereas the voltage of the Peltier element increased fivefold in the final stage of the experiment.

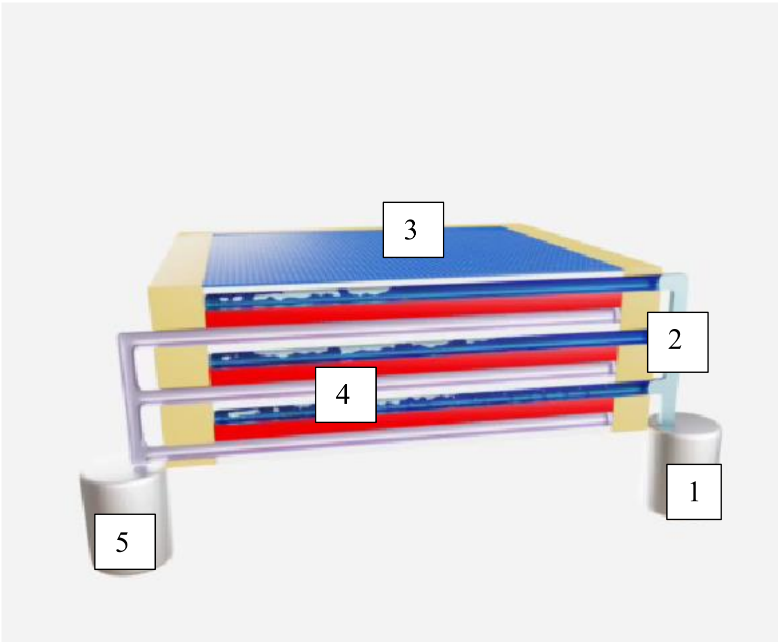


Picture 8- Comparison of Voltage Changes in the Solar Panel and Peltier Element Over Time

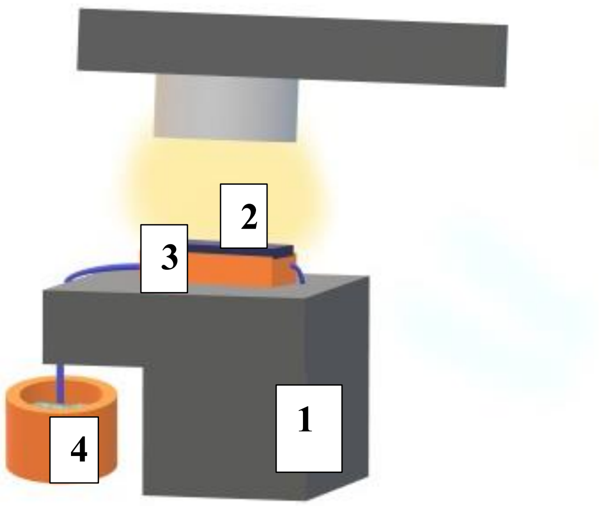
3. MULTI-STAGE MEMBRANE DISTILLATION CONSTRUCTION WITH SOLAR PANELS

A multi-stage design for membrane distillation has been developed to utilize the residual heat generated by solar panels for water desalination. The design consists of the following layers:

1. **Thermally Conductive Layer**: Made from an aluminum nitride plate due to its high thermal conductivity (>160 W m^-1 K^-1) and anti-corrosive properties in saline water.
2. **Vapor-Permeable Hydrophobic Porous Layer**: Constructed from a porous polystyrene membrane, which allows vapor to pass through.
3. **Hydrophilic Water-Permeable Layer and Condensation Layer**: Both layers are made from a quartz fiber glass membrane.



Picture 9- System Components 1) Tank with Contaminated Water 2) Pipes 3) Solar Panel 4) Membrane Distillation 5) Tank with purified water



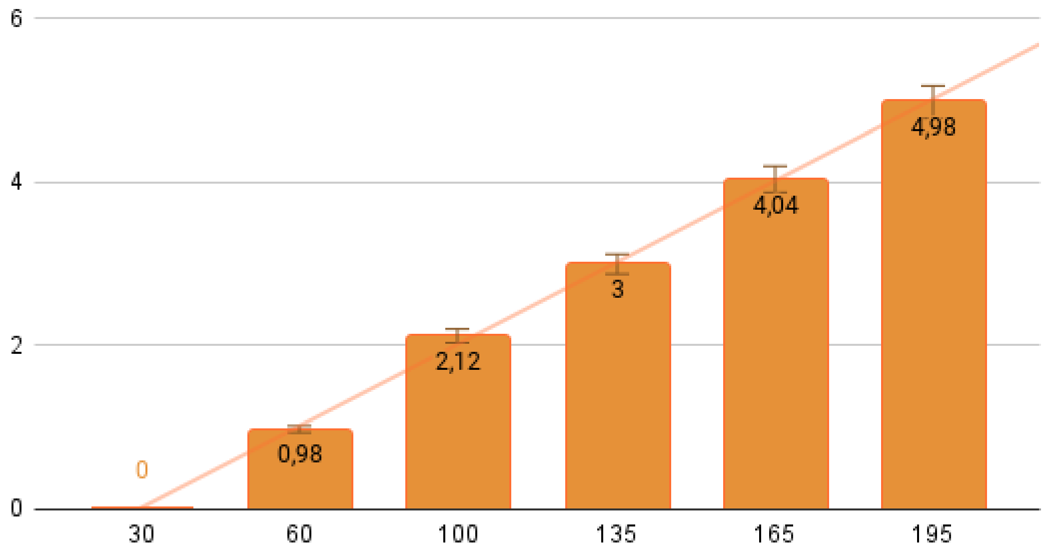
Picture 10- Water Purification System Under Laboratory Conditions 1) Tank with Contaminated Water 2) Solar Panel 3) Membrane Distillation 4) Tank with Purified Water

The design was tested under laboratory conditions. Water passes through the layers of the structure under the influence of heat, causing evaporation. Minerals and large particles are retained in the membrane layer. The water moves through the tubes due to the capillary effect caused by the pressure difference. The driving force for water evaporation and vapor condensation is the temperature gradient between the evaporation and condensation layers.

As a result of the experiment, the following relationship between cumulative water collection and time was obtained:

Time/ min	Water Collection/ (kg/m^2)
30	0
60	0,98
100	2,12
135	3,00
165	4,04
195	4,98

Picture 11- Cumulative Water Collection per Square Meter Over Time



Picture 12- Water Collection (kg/m²) to Time (min)

The membrane distillation system demonstrated an average productivity of 1 kg/m^2 of purified water every 39.2 minutes, showcasing high efficiency in the process of desalinating contaminated water. With the solar panel voltage remaining constant, the residual heat is effectively utilized for water purification, enabling simultaneous generation of energy and water purification.

CONCLUSION

The present study investigated the potential for enhancing the efficiency of solar panels through various innovative methods. The results obtained allow us to formulate the following conclusions:

1. On average, the temperature difference between the ambient environment and the solar panel was 1.66°C. This data was obtained using a thermocouple connected to the solar panel. The design of "floating" solar panels demonstrated the ability to reduce the system's temperature, thereby preventing overheating over prolonged periods and thus maintaining the efficiency of the batteries.
2. Over the course of 40 minutes of observation, the solar panel lost 7% of its initial voltage due to temperature increase, whereas the voltage of the Peltier element increased fivefold in the final stage of the experiment. This indicates the high efficiency of the Peltier element under temperature gradient conditions when used in conjunction with solar panels.
3. The multi-stage membrane distillation system demonstrated the capability to produce an average of 1 kg/m^2 of purified water every 39.2 minutes, confirming its effectiveness in desalinating contaminated water. The design allows for the use of residual heat from the solar panels for the water purification process, further increasing the overall efficiency of the system.

These results confirm the prospects of using "floating" solar panels, Peltier elements, and multi-stage membrane distillation systems to enhance the efficiency of solar panels and effectively utilize residual heat.

REFERENCES:

1. Anshul Awasthi, Akash,Kumar Shukla, Murali Manohar S.R, Chandrakant Dondariya , K.N. Shukla , Deepak Porwal, Geetam Richhariya /Review on Sun Tracking Technology in PV system. 2020

2. M.S. Abd-Elhady, Z. Serag, H.A. Kandil/ An innovative solution to the overheating problem of PV panels. 2018

3. Young-Kwan Choi/ A Study on Power Generation Analysis of Floating PV System Considering Environmental Impact. 2014

4. K.A. Moharram , M.S. Abd-Elhady, H.A. Kandil, H. El-Sherif/ Enhancing the performance of photovoltaic panels by water cooling. 2013

5. Geographic and technical floating photovoltaic potential. 2018

6. Wenbin Wang1, Yusuf Shi 1 , Chenlin Zhang1 , Seunghyun Hong 1 , Le Shi1 , Jian Chang1 , Renyuan Li 1 , Yong Jin1,2, Chisiang Ong1 , Sifei Zhuo1 & Peng Wang1/ Simultaneous production of fresh water and electricity via multistage solar photovoltaic membrane distillation. 2019

7. Бадёра Е. В. / АНАЛИЗ МЕТОДОВ ОПРЕСНЕНИЯ И ОБЕССОЛИВАНИЯ ДЛЯ РЕШЕНИЯ ПРОБЛЕМЫ НЕДОСТАТКА ПРЕСНОЙ ВОДЫ. 2021

8. S.A. El-Agouz , Mohamed E. Zayed , Ali M. Abo Ghazala , Ayman Refat Abd Elbar , Mohammad Shahin , M.Y. Zakaria, Khaled Khodary Ismaeil/ Solar thermal feed preheating techniques integrated with membrane distillation for seawater desalination applications: Recent advances, retrofitting performance improvement strategies, and future perspectives. 2022

9. Mariam N. Soliman [a], Fatima Z. Guen [a], Somaya A. Ahmed [a], Haleema Saleem [a], Mohd Junaid Khalil [b], Syed Javaid Zaidi/ Energy consumption and environmental impact assessment of desalination plants and brine disposal strategies. 2021

10. N. Ghaffour, S. Soukane, J.-G. Lee, Y. Kim , A. Alpatova/ Membrane distillation hybrids for water production and energy efficiency enhancement: A critical review. 2019

11. Ветлужский В.Н/ ТЕРМОЭЛЕКТРИЧЕСКИЕ ЯВЛЕНИЯ В ПОЛУПРОВОДНИКАХ. ИССЛЕДОВАНИЕ И ИХ ПРИМЕНЕНИЕ. 2022