

**Training in Research Methods and Modern Laboratory Equipment through  
Floating Solar Plant Design and Technology Analysis**



U N I V E R S I T Y *of*  
**LOUISIANA**  
L A F A Y E T T E ®

**Summer Research Internship**

Master's in electrical engineering in Smart Grids and Buildings

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## **Glossary**

**PV** Photovoltaic

**GPV** Ground Photovoltaic

**FPV** Floating Photovoltaic

**SAM System** Advisor Model

**AC** alternating current

**DC** direct current

**BOS** balance of system

**EBOS** electrical balance of system

**SBOS** structural balance of system

**ESS** energy storage system

**LCOE** levelized cost of energy

**NPV** net present value

**GCR** ground coverage ratio

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## Summary

This comprehensive report presents a detailed analysis and comparison of ground-mounted and floating photovoltaic (PV) systems, with a focus on their design, costs, energy efficiency, environmental impact, and integration into renewable energy systems. The study specifically examines the design of a 1 MW floating PV system and contrasts it with an equivalent ground-mounted PV system. The report emphasizes the potential of floating PV technology as an innovative solution to land constraints, highlighting its enhanced energy efficiency due to the cooling effect of water and additional environmental benefits such as reduced water evaporation. However, it also acknowledges the higher installation and maintenance costs associated with floating PV systems. To support its analysis, the report utilizes advanced modeling software, including the System Advisor Model (SAM), to simulate system performance and evaluate the Levelized Cost of Energy (LCOE). The findings underscore the promise of floating PV systems in contributing to a sustainable energy future while emphasizing the importance of further research and development to optimize cost-efficiency and minimize environmental impacts.

# 1. Introduction

## 1.1 Overview of the Laboratory and Internship Context



*Figure 1: View of Louisiana Solar Energy Laboratory*

The Louisiana Solar Energy Lab at the University of Louisiana at Lafayette is an esteemed outdoor solar testing facility in the southeastern United States dedicated to the advancement of solar technology and sustainability. The lab conducts extensive research on solar module degradation, soiling, and energy forecasting, playing a pivotal role in education, workforce development, and the expansion of solar energy curricula at the university. This lab ushered in a new era with state-of-the-art technology to support cutting-edge research and collaboration. Its mission is to foster economic growth through top-tier sustainable energy research while empowering the next generation of innovators through education and workforce development.

Complementing this mission is the Energy Efficiency and Sustainable Energy (EESE) Center, which brings together a diverse team of students, faculty, and staff to explore sustainable energy generation in solar and energy efficiency improvements. The lab collaborates with international faculty and students, sharing knowledge and resources to address global energy challenges. Research at the PART Lab focuses on optimizing solar panels and advancing energy efficiency through innovations in HVAC systems, smart buildings, and energy audits. Supported by grants and funding, the lab's work influences policies and drives the transition to a sustainable energy future.

Ultimately, the Louisiana Solar Energy Lab is at the forefront of innovation and sustainability, spearheading renewable energy research and education to prepare students to build a world powered by clean, reliable, and sustainable energy.

## 1.2 Objectives of the Internship

The shift to sustainable energy is a crucial global initiative, with solar power playing a pivotal role in meeting climate targets. Among the innovative strategies in this realm, floating solar power systems have emerged as a promising solution to address land limitations and boost efficiency. This document is dedicated to advancing the comprehension and application of floating solar technology by pursuing several key objectives.

Firstly, the aim is to deepen the comprehension of the fundamentals of solar power plants. A strong understanding of these principles, especially in the context of floating solar systems, is vital for successfully navigating the complexities of solar energy design and implementation.

Secondly, proficiency will be developed in using advanced design software tools for the simulation and modeling of floating solar plants. Employing these tools will enhance the capacity to design optimized systems that maximize energy output and minimize costs and environmental impact.

Thirdly, gaining practical experience with laboratory equipment is vital. This hands-on objective will facilitate the testing and validation of design models, ensuring that theoretical concepts translate effectively into real-world applications within floating solar technology.

Lastly, conducting a comprehensive energy analysis of floating solar systems is a critical objective. By thoroughly assessing energy yield, efficiency enhancements, and environmental impact, valuable insights will be generated to guide future advancements in floating solar technology.

## 2. Methods and Procedures

### 2.1 Fundament of a solar power plant

The journey towards a sustainable future begins with harnessing the limitless power of renewable energy. Defined as energy sourced from natural processes that are continuously replenished, renewable energy stands at the forefront of combating climate change and ensuring a cleaner planet for generations to come. There are various types of renewable energy, each playing a crucial role in reducing our dependence on fossil fuels and decreasing carbon emissions.

**Types of Renewable Energy:**

1. **Solar Energy:** Capturing sunlight and converting it into electricity through photovoltaic (PV) systems or solar thermal systems.
2. **Wind Energy:** Utilizing the power of wind through turbines to generate electricity.
3. **Hydropower:** Generating electricity from the flow of water, typically from dams or rivers.
4. **Geothermal Energy:** Tapping into the Earth's internal heat to produce electricity and provide direct heating.
5. **Biomass Energy:** Converting organic materials into electricity, heat, or biofuels.

### **Solar Photovoltaic (PV) Systems:**

Solar Photovoltaic (PV) systems are among the most versatile and rapidly advancing technologies in the renewable energy sector. These systems convert sunlight directly into electricity using semiconducting materials, predominantly silicon. Solar PV systems can be categorized based on their applications:

- **Residential Solar PV:** Typically installed on rooftops, residential systems range from 3 kW to 10 kW. These systems enable homeowners to generate their own clean energy, thereby reducing electricity bills and contributing to a greener environment.
- **Commercial Solar PV:** Larger systems, usually ranging from 10 kW to 100 kW, are installed on commercial buildings. These installations assist businesses in lowering operational costs and underscore their commitment to sustainability.
- **Utility-Scale Solar PV:** These extensive solar farms can generate hundreds of megawatts and supply electricity to the grid. Utility-scale systems are crucial for transitioning from fossil fuels to renewable energy sources.

Additionally, there are **community solar PV** and **standalone solar PV** systems. Community Solar PV allows multiple individuals or entities to benefit from a shared solar system, often located off-site. This model democratizes access to solar energy, particularly for those unable to install systems on their own properties. Standalone Solar PV systems operate independently of the grid and are commonly used in remote or off-grid areas, providing essential electricity in regions lacking reliable grid access.

### **Solar Power Plants**

Solar PV technology, or photovoltaic technology, converts sunlight directly into electricity using solar cells, typically made of silicon. These cells absorb sunlight and release electrons, creating an electric current.

A solar power plant is a large facility that transforms solar radiation—encompassing light, heat, and ultraviolet rays—into electricity. Predominantly using photovoltaic panels to capture sunlight, these plants generate electricity that is supplied to homes, industries, and the grid. This

process of clean energy production is entirely ecological, generating no pollutants, and represents one of the most efficient renewable energy sources available today.

Given the benefits of solar energy over fossil fuels, solar power plants play a vital role in reducing carbon emissions and promoting the global transition to sustainable energy. They offer a reliable and eco-friendly solution that can be scaled to meet increasing energy demands, thereby contributing to a more sustainable future.

### **Components of a Solar Power Plant:**

A solar power plant is a symphony of various components working in harmony to capture and convert sunlight into usable electricity. The key components include:

- **Solar Panels:** The heart of the system, where sunlight is converted into electricity.
- **Inverters:** Convert the direct current (DC) generated by solar panels into alternating current (AC) used by the electrical grid and most appliances.
- **Mounting Systems:** Structures that hold the solar panels in place, either on rooftops, on the ground, or floating on water bodies.
- **Electrical Balance of System (EBOS):** Includes wiring, switches, and other electrical components needed to connect the solar panels to the inverter and grid.
- **Battery Storage:** Stores excess energy generated during the day for use during nighttime or cloudy days, enhancing the reliability of solar power.

### **Solar Safety:**

Safety is paramount in solar power plants, encompassing both installation and operational phases. The main safety concerns include:

- **Electrical Hazards:** Solar systems generate high-voltage electricity, which can be dangerous if not handled properly. Proper grounding, insulation, and protective equipment are essential.
- **Mechanical Hazards:** The installation process involves working at heights and handling heavy equipment, requiring safety protocols to prevent falls and injuries.
- **Site Hazards:** Solar power plants, especially utility-scale ones, can cover vast areas. Ensuring safe site access, clear signage, and proper maintenance practices are crucial.

Several organizations actively work to establish and enforce safety standards in the solar industry, including the National Renewable Energy Laboratory (NREL), the Solar Energy Industries Association (SEIA), and the Occupational Safety and Health Administration (OSHA).

## **2.2 PV Systems and Renewable Energy Integration**



As the global community increasingly adopts sustainable energy solutions, photovoltaic (PV) systems and renewable energy integration are central to this shift. These technologies offer significant potential to reduce our dependence on fossil fuels and mitigate the effects of climate change.

Integrating renewable energy into existing power grids is essential for maximizing the advantages of solar and other renewable sources. This integration involves several key strategies and technologies:

**Grid Integration:** Renewable energy sources, such as solar and wind, can be variable in nature. Effective grid integration is necessary to seamlessly incorporate these sources into the power grid while maintaining a balance between supply and demand. This requires sophisticated grid management and infrastructure improvements.

**Energy Storage:** To address the intermittency of renewable sources, energy storage solutions like batteries and pumped hydro storage are crucial. These technologies store excess energy during periods of high production and release it when production is low, ensuring a stable energy supply.

**Demand Response:** Adjusting energy consumption patterns based on the availability of renewable energy helps maintain grid balance. For example, scheduling electric vehicle charging or industrial processes during periods of high renewable energy production can optimize resource use.

**Smart Grids:** The development of smart grids involves implementing advanced technologies for monitoring and managing energy distribution. Smart grids improve the efficiency and reliability of integrating renewable sources by enabling real-time adjustments and enhanced resource management.

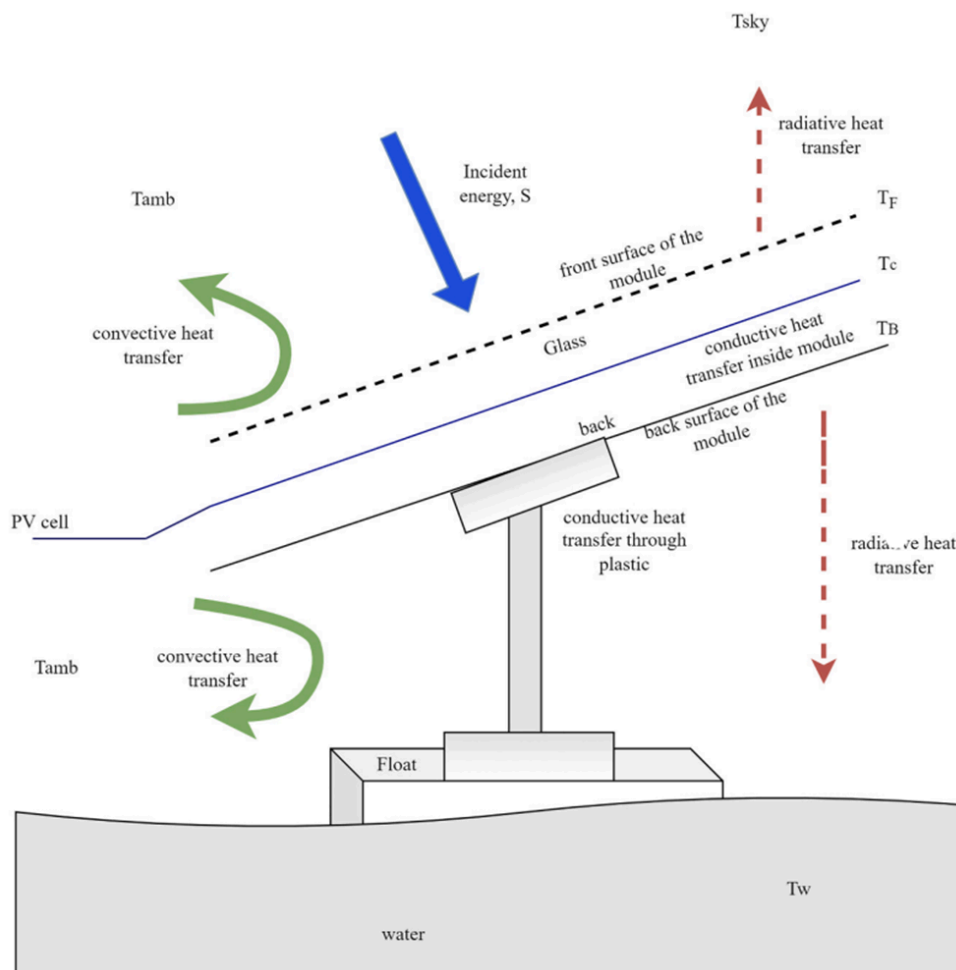
The effective combination of PV systems and renewable energy integration strategies represents a significant advancement toward a sustainable energy future. By leveraging these technologies, we can reduce our carbon footprint, enhance energy security, and contribute to a cleaner, greener planet.

## 2. 3 Design Study of Floating PV Systems

Floating photovoltaic (PV) systems represent an innovative approach to harnessing solar energy by installing PV panels on bodies of water, such as lakes, reservoirs, or ponds. This technology utilizes otherwise unused water surfaces, offering a viable alternative to land-based solar farms and providing several advantages, including enhanced efficiency and conservation benefits.

One of the primary advantages of floating PV systems is their superior efficiency compared to land-based systems. This enhanced performance is largely attributed to the cooling effect of the water surface, which helps maintain lower panel temperatures and thereby improves overall energy output. The cooling processes involved include:

1. **Cooling Effect of Water:** Water aids in keeping the panels cool through convection, where moving water carries away heat from the panels, lowering their temperature. Additionally, evaporation contributes by removing heat as water turns into vapor.
2. **Conduction:** Heat transfer from the panels to the water below also plays a role. As the panels heat up, they conduct heat into the water, which helps in cooling them down.
3. **Radiation:** The panels also release heat into the air. As they absorb sunlight, they emit heat, which helps in preventing overheating.



*Figure 2: Heat transfer process in FPV*

These processes—convection, evaporation, conduction, and radiation—work in conjunction to maintain optimal panel temperatures and enhance system efficiency.

The design of floating PV systems involves several critical components. The floating structures supporting the solar panels must be engineered to endure varying weather conditions and fluctuating water levels. These buoyant platforms are designed to maintain structural integrity and operational stability. Effective anchoring systems are essential to prevent drift and secure the platform's position relative to the water body. The design and implementation of these anchoring systems present technical challenges that are crucial for successful deployment. Additionally, the durability of the construction materials is paramount, as they must resist water and environmental factors to ensure long-term performance.

Floating PV systems also offer significant benefits, such as land conservation. By utilizing water surfaces, they are particularly well-suited for areas where land is scarce or expensive. Moreover, covering water bodies with floating solar installations helps to reduce evaporation rates, contributing to water conservation in reservoirs and lakes. The improved energy efficiency of floating solar panels, due to the cooling effect of water, further distinguishes them from traditional land-based systems.

However, floating solar technology is not without its challenges. Maintenance can be more complex and costly due to the need for specialized equipment and safety measures for operations on water. Additionally, assessing the environmental impact of floating solar systems on aquatic ecosystems and water quality is essential. Potential concerns include effects on aquatic life and water chemistry, which necessitate measures to mitigate any adverse impacts.

## 2. 3 Design of 1 MW Ground PV and Floating PV Systems

This study investigates the design parameters for a 1 MW ground-mounted photovoltaic (PV) system and a floating PV system using identical module and inverter specifications. The chosen module for both systems is the SunPower SPR 314E, paired with the Sungrow Power Supply Co., Ltd. SG125HV [600V] inverter. The design incorporates a DC-to-AC ratio of 1.14, with the array consisting of 3,168 modules arranged into 176 strings, each containing 18 modules. This configuration results in a total module area of 5,167 square meters.

In both GPV and FPV systems, the panels are positioned with an azimuth angle of 180 degrees. However, there is a variance in the tilt angles. The GPV system has a tilt of 25 degrees, while the FPV system is set at a tilt of 10 degrees. The ground coverage ratio (GCR) represents the proportion of the area covered by the PV array relative to the ground area. For the FPV system, the GCR is 0.7, whereas for the GPV system, it is 0.55. The GCR for GPV was calculated based on measurements conducted at the Louisiana Solar Energy Lab, where the length of the side of one row was 356 cm, and the vertical spacing between adjacent rows was 643 cm.



Figure 3: Ground coverage ratio measurement

The System Advisor Model (SAM) does not offer a specific module for floating PV system design. Consequently, the primary parameter available for FPV systems in SAM is the temperature coefficient. For this study, the temperature coefficient values are  $a = -3.483$  and  $b = -0.105$ , with a temperature difference of  $3^{\circ}\text{C}$ .

Soiling losses, which are influenced by the accumulation of dirt and dust on the PV modules, are higher for GPV systems at 5%, compared to 1% for FPV systems. This difference is attributed to the reduced exposure of FPV modules to dust due to their placement on water bodies.

In terms of financial considerations, the total installation cost per watt for GPV systems, based on NREL data from 2021, is \$1.43/W. This data includes installation costs for various system sizes ranging from 2 MW to 50 MW. Using trend analysis, the cost for FPV systems is estimated at \$1.78/W.

System size	Total installation cost per capacity	Module cost	Inverter cost	Structural BOS	Electrical BOS	Install Labor & Equipment	EPC Overhead-Installer margin and overhead	Permitting, Inspection, Interconnection	Shipping/handling	Sales Tax (if any)	Contingency	Engineering and developer overhead	EPC/Developer Profit
2	\$1.68	0.33	0.04	0.47	0.15	0.07	0.15	0.05	0.01	0.05	0.06	0.14	0.10
5	\$1.46	0.33	0.04	0.43	0.11	0.06	0.07	0.05	0.02	0.05	0.05	0.12	0.08
10	\$1.29	0.33	0.04	0.37	0.10	0.06	0.05	0.04	0.02	0.04	0.05	0.07	0.07
50	\$1.05	0.33	0.04	0.26	0.08	0.06	0.03	0.04	0.02	0.04	0.04	0.05	0.05
1	1.78	0.33	0.04	0.53	0.15	0.07	0.15	0.05	0.01	0.05	0.06	0.16	0.11
2	1.65	0.33	0.04	0.48	0.14	0.07	0.12	0.05	0.01	0.05	0.06	0.14	0.10
5	1.47	0.33	0.04	0.42	0.12	0.06	0.09	0.05	0.01	0.05	0.05	0.11	0.08
10	1.34	0.33	0.04	0.37	0.11	0.06	0.07	0.04	0.01	0.04	0.05	0.09	0.07
50	1.02	0.33	0.04	0.26	0.08	0.06	0.01	0.04	0.00	0.04	0.04	0.04	0.05

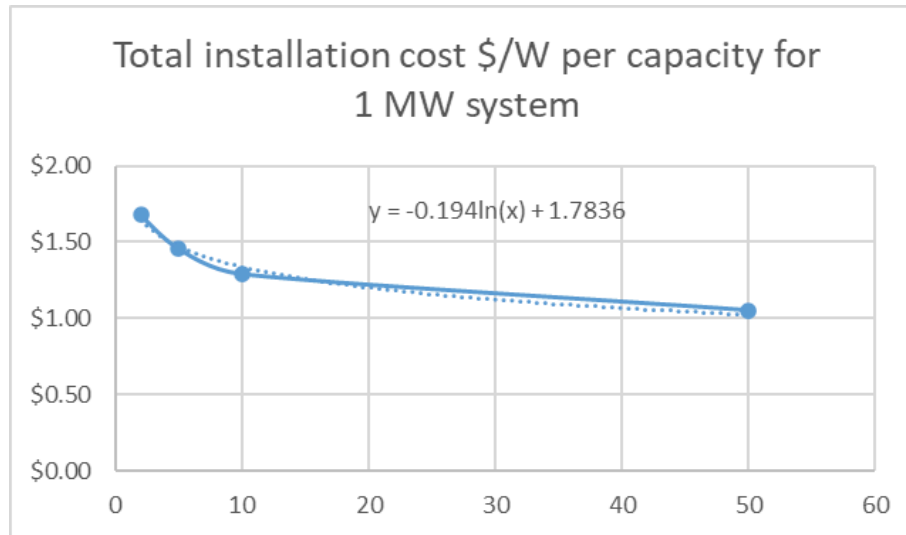


Figure 4: Calculation of total installation cost for 1 MW FPV system\_2021

For the year 2023, GPV installation costs were extrapolated from NREL's data, which includes systems of 8 kW, 3 MW, and 100 MW. Trend analysis was used to estimate the cost for a 1 MW system. For FPV systems, a cost ratio of 0.8 relative to GPV systems was applied based on 2021 data. This results in estimated installation costs for FPV systems in 2023 of \$2.38/W, compared to \$1.90/W for GPV systems.

System size kw	Total installation cost per capacity\$
10000	1161
3000	1761
8	2682
1000	2330.3

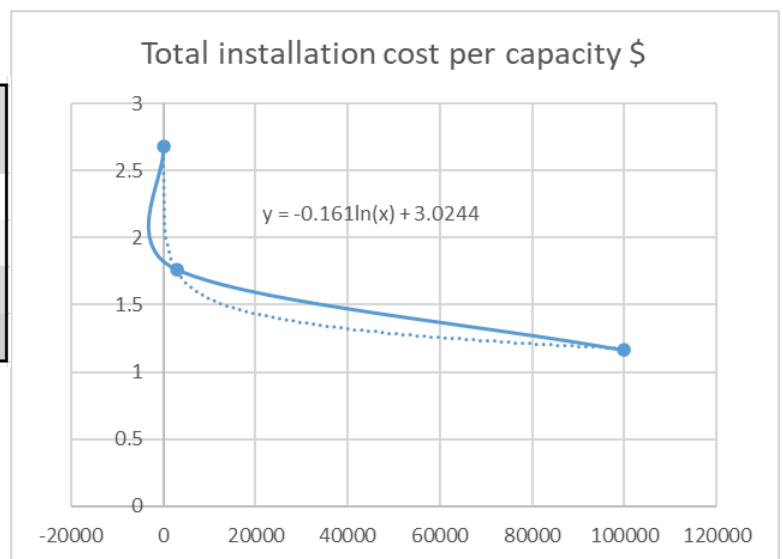


Figure 5: Calculation of total installation cost for 1 MW FPV system

	2021 - 1 MW		2023 - 1MW	
System type	GPV	FPV	GPV	FPV
Total installation cost per capacity \$/W	1.43	1.78	1.9	2.38
LCOE \$/KWh	4.71	5.66	6.32	7.33

*Figure 6: Installation cost of capacity and LCOE for 2021 and 2023*

## 2.5 Software Implementation:

In the design and analysis of photovoltaic (PV) systems, software implementation plays a crucial role in optimizing performance and evaluating feasibility. Specialized software tools, such as System Advisor Model (SAM), PV\*Sol, HOMER, and PVSyst, are employed to model and simulate various aspects of the PV system. These tools enable the input of key parameters, such as module and inverter specifications, system layout, and environmental conditions, to predict energy production, efficiency, and financial outcomes. By performing detailed simulations and analyses, the software helps identify optimal configurations, assess system performance, and provide recommendations for improvements. This process not only supports informed decision-making but also ensures the development of efficient and cost-effective solar power systems.

### 2.5.1 System Advisor Model(SAM)

The System Advisor Model™ (SAM™) is an advanced desktop application developed for the techno-economic analysis of renewable energy technologies. Created by the National Renewable Energy Laboratory (NREL) in collaboration with Sandia National Laboratories, SAM was initially released in 2005 for internal use by the



U.S. Department of Energy's Solar Energy Technologies Program. Its primary purpose was to support systems-based analysis of solar technology improvements within the program. The first public version of SAM was launched in August 2007, initially focusing on solar technologies, including photovoltaic (PV) systems and concentrating solar power (CSP) parabolic trough systems.

Since its introduction, SAM has undergone significant evolution. In 2010, the model was rebranded to the "System Advisor Model" to reflect its expanded capabilities beyond solar

technologies. SAM now supports a diverse array of renewable energy systems, including wind power, marine energy, geothermal power, and biomass combustion, in addition to its original focus areas. This expansion allows SAM users to model and analyze a wide range of energy technologies using a unified platform.

SAM's modeling capabilities extend to both technical performance and financial feasibility. It provides financial models tailored to various project types, such as residential and commercial systems where the renewable energy system is located behind the meter to reduce electricity bills. It also supports power purchase agreements (PPAs) for grid-connected systems that generate revenue through power sales, as well as third-party ownership arrangements where a separate entity owns the system installed on a customer's property. These features enable users to evaluate different system configurations, optimize financial outcomes, and design effective incentive structures.

The software is updated regularly, with new versions typically released twice a year to incorporate emerging technologies and financing options. As of fall 2013, NREL began releasing one new version annually with periodic updates as necessary. Over its lifetime, SAM has been downloaded by more than 35,000 users worldwide, including manufacturers, project developers, policy analysts, and researchers. These stakeholders use SAM to assess technical performance, optimize financial returns, and support the development of innovative clean energy solutions. SAM's widespread adoption and its role in facilitating informed decision-making underscore its significance in advancing the renewable energy sector and promoting a sustainable energy future.

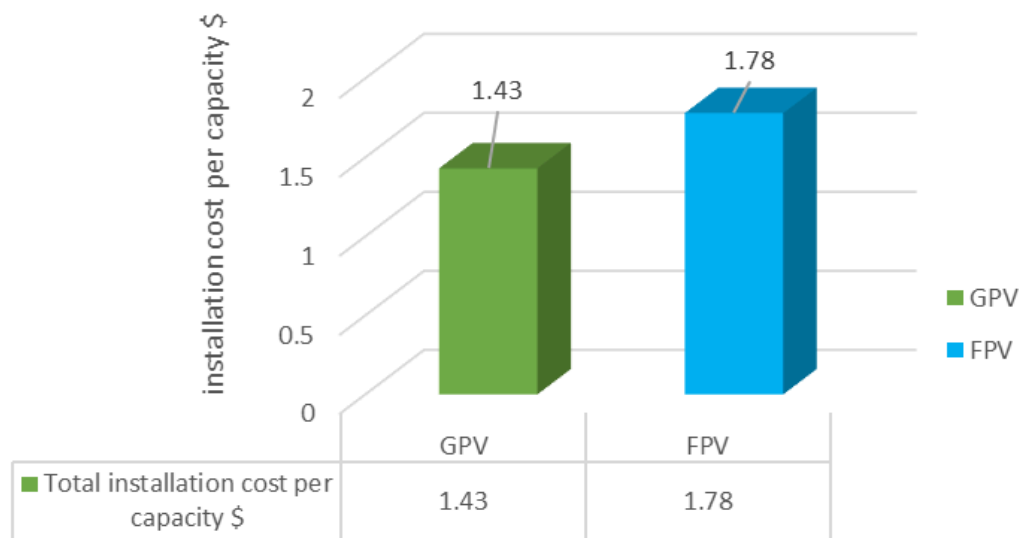
## **Results and Analysis**

### **3.1 Critical Analysis of Floating PV Design and Costs**

#### **LCOE Analysis**

The levelized cost of energy (LCOE) for floating photovoltaic (FPV) systems is influenced by a variety of factors, including albedo, ambient temperature, module operating temperature, heat loss, soiling and mismatch losses, tilt angle, ground coverage ratio, and environmental loads. It's worth noting that the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM) currently lacks a specific option for modeling FPV systems. In 2021, the installation costs per watt were estimated at \$1.43 for ground-mounted photovoltaic (GPV) systems and \$1.78 for FPV systems. The disparity in installation costs is mainly due to the higher balance of system (BOS) costs associated with FPV systems, particularly in structural components (SBOS) such as floats, anchoring, and mooring systems, compared to electrical BOS (EBOS). As a result, the LCOE calculated by SAM was \$4.71/kW for GPV and \$5.66/kW for FPV in 2021.

### 1 MW \_total installation cost per capacity \$/W \_ 2021



Benchmark cost of GPV & FPV system

### 'LCOE \$/KWh' 2021

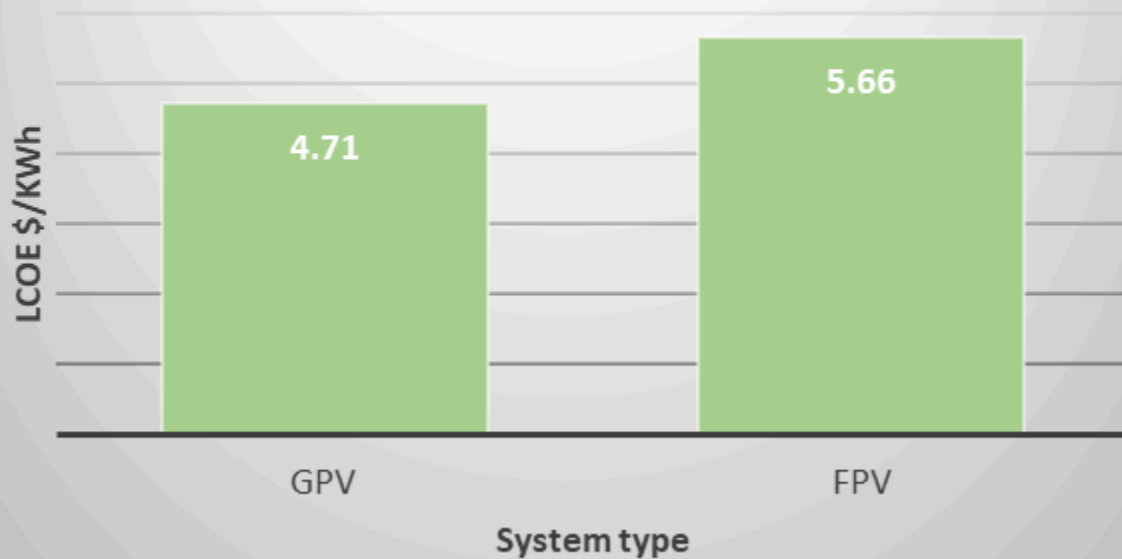


Figure 7: Cost benchmarking for 2021



Due to inflation and various other factors, installation costs rose by 2023, with GPV costs climbing to \$1.91/W and FPV costs increasing to \$2.38/W. As a result, the LCOE also went up, reaching \$6.32/kW for GPV systems and \$7.33/kW for FPV systems. Despite the higher costs associated with FPV systems, their improved efficiency and potential environmental benefits position them as a competitive option as technology continues to advance.

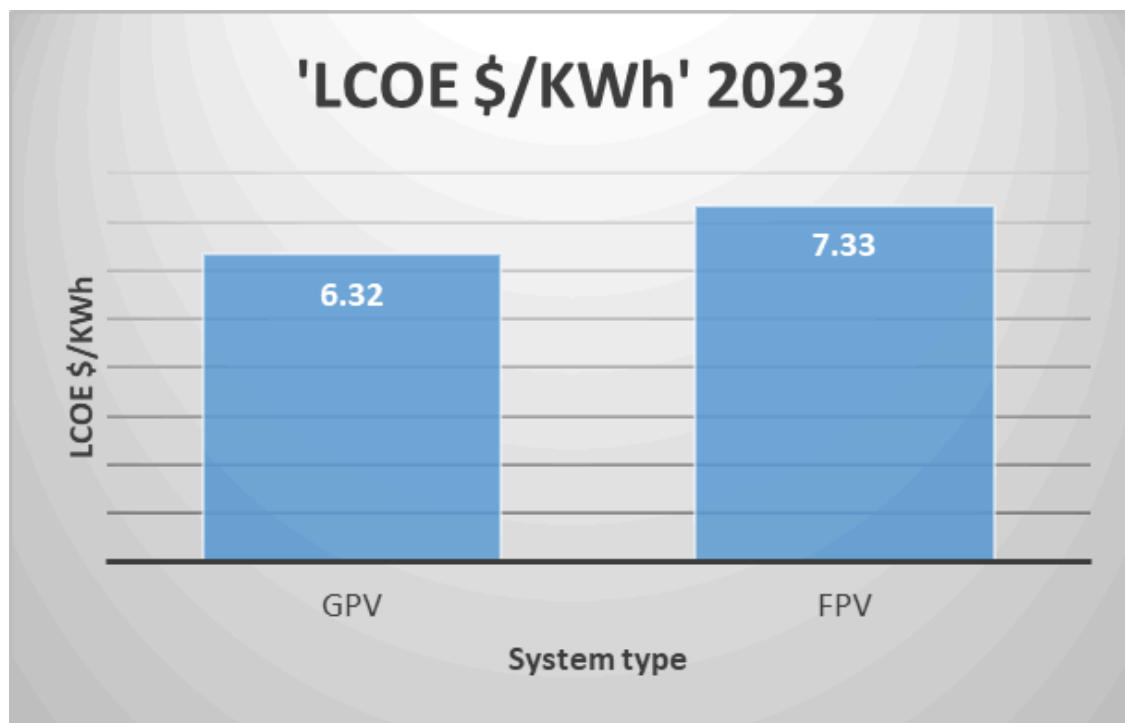
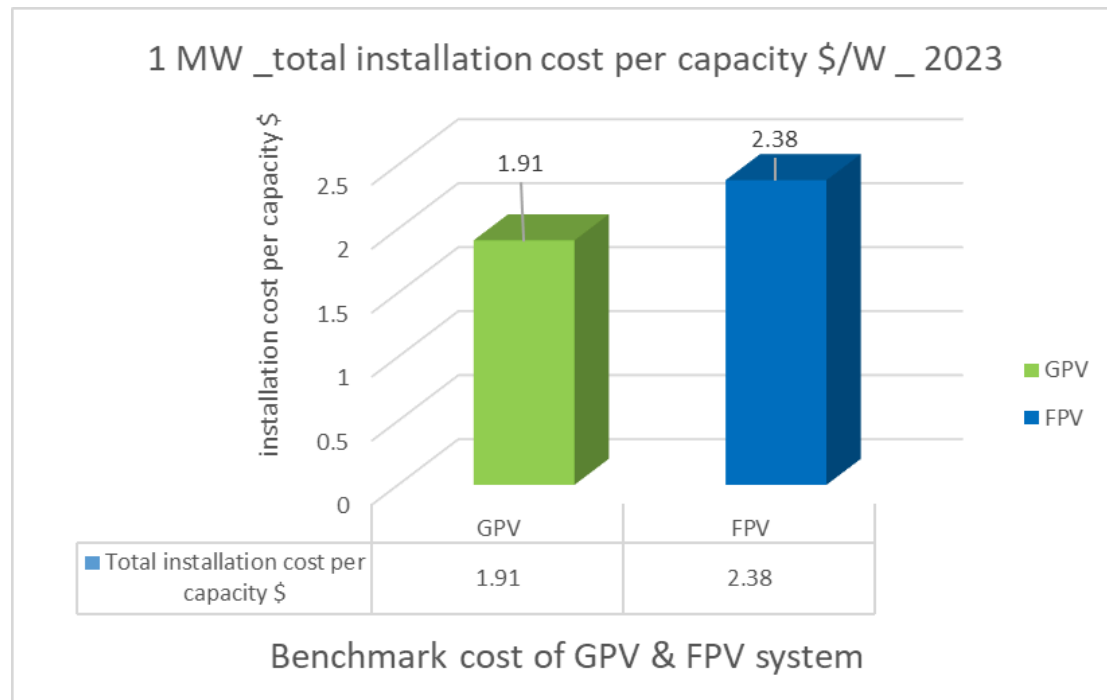


Figure 8: Cost benchmarking for 2023

Model Component	GPV	FPV
System size	1 MW	1 MW
Tilt angle	25	10
GCR	0.55	0.7
Soiling loss	5%	1%
Heat loss factor	a = -3.62	a = -3.483
	b = -0.075	b = -0.105
Fixed operating cost	18	15.5
Analysis period	30	30
Inflation rate	2.50%	2.50%
Internal rate of return	5.10%	5.10%
Project intern debt	71.80%	71.80%
Nominal debt interest rate	5%	5%
Effective tax rate	25.74%	25.74%
LCOE \$/kW	6.32	7.33

*Figure 9: LCOE inputs*

### 3.2 4E Framework Analysis

#### Energy Analysis

Floating photovoltaic (FPV) systems have been shown to offer enhanced energy efficiency compared to ground-mounted photovoltaic (GPV) systems. This is primarily due to the cooling effect generated by the underlying water surface, which helps to maintain lower temperatures for the PV modules. As a result, heat-induced efficiency losses are reduced, leading to an overall increase in energy output. Additionally, FPV systems are less susceptible to soiling losses as their placement on water surfaces minimizes exposure to dust and dirt, further enhancing energy production. The design parameters of FPV systems, including a lower tilt angle of 10° compared to 25° for GPV systems and a higher ground coverage ratio (GCR), are optimized to make the most of available water surfaces. This strategic design significantly boosts energy yield by allowing more efficient use of the area, ultimately maximizing energy production in FPV systems.

## **Economic Analysis**

The total installation costs for FPV are higher than GPV, primarily due to increased balance of system (BOS) expenses. These elevated costs are particularly evident in the structural BOS (SBOS) components, which encompass floats, anchoring, and mooring systems. In 2023, the estimated installation costs for FPV systems are \$2.38 per watt, compared to \$1.90 per watt for GPV systems. Although FPV systems may benefit from enhanced efficiency, resulting in potentially competitive Levelized Cost of Energy (LCOE) values, the LCOE for FPV systems remains higher than that of GPV systems. Specifically, 2023 estimates place the LCOE at \$7.33 per kilowatt for FPV systems, compared to \$6.32 per kilowatt for GPV systems. Over time, the economic feasibility of FPV systems is expected to improve as technological advancements drive cost reductions. However, the complexity of maintaining FPV systems on water bodies may contribute to higher ongoing maintenance costs compared to GPV systems.

## **Environmental Impact**

Floating photovoltaic (FPV) systems provide substantial environmental benefits, especially in terms of land and water conservation. By harnessing water surfaces for solar installations, FPV systems minimize the demand for land, alleviating competition for valuable land resources that could otherwise be allocated for agriculture or urban development. Additionally, FPV systems aid in water conservation by reducing evaporation from reservoirs and lakes. This is particularly important in water-scarce regions, as the solar panels offer shade and mitigate direct sunlight exposure. Nevertheless, it is crucial to thoroughly assess the environmental impacts on aquatic ecosystems, as FPV systems have the potential to impact water quality and aquatic life by altering sunlight penetration and water temperature. Comprehensive environmental evaluations are imperative to mitigate these potential effects. Furthermore, FPV systems play a role in reducing the carbon footprint by displacing fossil fuel-based power generation, aligning with broader efforts to decrease greenhouse gas emissions and address climate change.

## **Evaporation**

Floating photovoltaic (FPV) systems play a significant role in reducing water evaporation rates by covering the water surface, thus mitigating the effects of direct sunlight exposure and wind, which are primary drivers of evaporation. Studies have indicated that FPV systems can achieve impressive evaporation reduction efficiencies ranging from 60.20% to 70.70%, as exemplified by their implementation in the Passaúna Reservoir, Brazil. This reduction in evaporation is particularly beneficial in water-scarce regions and areas where reservoirs are crucial for water supply. Apart from reducing water evaporation, FPV systems also help maintain cooler water temperatures, which not only enhances the efficiency of the PV panels by preventing heat-induced performance losses but also offers additional benefits. Furthermore, the larger the surface area covered by FPV systems, the more significant the water savings, thereby potentially impacting water resource management, particularly during water scarcity periods. In summary,

FPV systems not only provide renewable energy but also play a critical role in conserving water resources.

## **4. Discussion**

The utilization of floating photovoltaic (FPV) systems represents a promising leap forward in solar energy generation, particularly in alleviating land-use constraints and improving energy efficiency. Nevertheless, this study underscores several constraints that may impede the wider application and optimization of FPV technology. A significant challenge is the lack of specialized software tailored specifically for designing and simulating FPV systems. Existing tools, such as the System Advisor Model (SAM), lack the necessary functions to accurately model FPV-specific variables such as water cooling effects, floating structures, and anchoring systems, thus limiting result accuracy. Additionally, the regional variations in leasing regulations for water bodies have a considerable impact on the financial viability and operational logistics of FPV projects. Local regulations and leasing conditions can vary widely, at times rendering leases cost-prohibitive or imposing stringent environmental restrictions. This variability complicates standardization and necessitates customized approaches for each project to navigate local legal and regulatory frameworks. In conclusion, while FPV systems demonstrate the potential to advance sustainable energy solutions, it is crucial to address these constraints through improved software tools and a deeper understanding of regulatory challenges in order to optimize FPV technology and facilitate its widespread adoption as an alternative to traditional ground-mounted solar systems.

## **5. Conclusion**

The analysis underscores the potential of floating photovoltaic (FPV) systems as an attractive alternative to traditional ground-mounted photovoltaic (GPV) systems. Despite higher installation costs, primarily due to increased structural balance of system (SBOS) expenses, FPV systems offer notable advantages in energy efficiency, environmental impact, and water conservation.

The cooling effect from water bodies under FPV installations enhances energy output by reducing heat-induced efficiency losses, making FPV systems an effective solution for maximizing energy yield. Additionally, FPV systems can significantly reduce evaporation rates, which is especially beneficial in water-scarce regions, providing both renewable energy generation and water resource management benefits.

However, challenges such as higher maintenance costs and the need for thorough environmental impact assessments persist. As technology advances, anticipated improvements are expected to lower costs and enhance the economic viability of FPV systems, making them more competitive with traditional GPV systems.

FPV systems offer an innovative approach to solar energy generation that aligns with global sustainability goals, providing a compelling solution for regions with limited land availability and abundant water resources. Continuous research and development will be crucial to overcoming current challenges and fully realizing the potential of FPV technology in the transition to a sustainable energy future.

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