

**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 Internship(M1)

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 study presents the difference between designing ground-mounted and floating photovoltaic systems and a thorough cost analysis, particularly the LCOE. For the same capacity, a 1 MW power plant showed the different parameters used to design a plant and also the different financial parameters. The report emphasizes the advantages of a floating power plant over ground-mounted PV, highlighting its efficiency and water evaporation. However, it also discussed the challenges of floating power plants' higher installation costs, reasoning the structural balance of the system. To enhance the quality of analysis, this report used the System Advisor Model (SAM) software from NREL (National Renewable Energy Laboratory) to design both power plants. At the end of the report, it also compares the LCOE from the years 2021 and 2023 and discusses the reason behind the increasing prices and the limitation of the analysis.

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 has started its journey with the vision of ensuring a reliable supply of energy from a clean and sustainable source to the world. It works to enable economic growth by providing world-class sustainable energy research, education, and outreach nationally and internationally. A key part of its mission is workforce development, where it equips students and professionals with the skills and knowledge needed to thrive in the energy industry. The lab has a 1.1 MW ground-mounted solar power plant, which supplies clean energy to the university and the research work. It has several categories of solar installation, such as thermal solar, rooftop solar, single-axis solar tracker, and dual-axis solar tracker, for testing. The power plant uses monocrystal, polycrystal, and thin film solar panels. This lab is equipped with numerous modern laboratory equipment as well as safety equipment. The research area is focused on sustainable power, including photovoltaic and concentrating solar thermal and energy efficiency, including energy audit and HVAC.

The work at the PART Lab is not just about research and education; it's about leading the way in our energy transition. By optimizing solar panels, enhancing energy efficacy through the study of HVAC systems and smart buildings, and conducting energy audits, the lab's work is already shaping policy and accelerating our energy transition. The Louisiana Solar Energy Lab is not following the trend-it's setting it. It's leading the transformation and moving education forward, ensuring our students are ready to power a clean, reliable, sustainable energy future.

1.2 Objectives of the Internship

The transition to sustainable energy represents a critical global initiative, with solar energy playing a pivotal role in achieving climate goals. The following document is dedicated to advancing the comprehension and application of floating solar technology by addressing a number of key objectives. Firstly, it aims to foster a comprehensive understanding of solar power plant fundamentals and to facilitate hands-on experience with modern laboratory equipment, particularly within the context of floating solar systems, as this forms the cornerstone for the successful design and implementation of solar energy projects. Secondly, the document seeks to cultivate expertise in the use of advanced software tools for designing and conducting simulations for both ground and floating solar plants. These tools are integral to the development of systems that optimize energy output while also mitigating costs and environmental impact. Finally, the document seeks to conduct an analysis of the cost benchmarking for floating solar systems in comparison to ground-mounted systems. Moreover, it includes a discussion on the 4E analysis, which encompasses energy analysis, economic analysis, environmental impact, and evaporation.

2. Methods and Procedures

2.1 Fundament of a solar power plant

The journey towards a sustainable future begins with harnessing the boundless potential of renewable energy. This type of energy is derived from natural processes that perpetually replenish themselves. Utilizing renewable energy is essential in combatting climate change and preserving a clean environment for future generations. There are various forms of renewable energy, each contributing to our reduced dependence on fossil fuels and decreased carbon emissions.

Types of Renewable Energy:

1. **Solar Energy:** Directly captures sunlight and converts it into electricity through photovoltaic (PV) or solar thermal systems.
2. **Wind Energy:** Utilizing the power of wind through turbines to generate electricity.
3. **Hydropower:** Generating electricity from water flow, 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 contribute to electricity bills and join to build a sustainable environment.
- **Commercial Solar PV:** Larger systems, usually 10 kW to 100 kW, are installed on commercial buildings. These installations assist businesses to decrease operational costs and underscore their commitment to sustainability.
- **Utility-Scale Solar PV:** These installations produce massive amounts of electricity mostly 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 also **community solar PV** and **standalone solar PV** systems. Community Solar PV shares the produced electricity for multiple individuals or entities from one system, often located off-site, and particularly for those unable to install systems on their properties. Standalone Solar PV systems are off-grid and are commonly used in remote areas, providing essential electricity in regions lacking reliable grid access.

Solar Power Plants

A solar power plant is a large facility that converts solar radiation—including light, heat, and ultraviolet rays—into electricity. By primarily utilizing photovoltaic panels to harness sunlight, these plants produce electricity that can be used in homes, industries, and the grid. This method of generating clean energy is completely environmentally friendly, producing no pollutants, and represents one of the most effective renewable energy sources currently available.

Due to the advantages of solar energy over fossil fuels, solar power plants play a crucial role in reducing carbon emissions and advancing the global shift to sustainable energy. They provide a dependable, eco-friendly solution that can be expanded to meet growing energy needs, thereby contributing to a more sustainable future.

Components of a Solar Power Plant:

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

- **Solar Panels:** The system's heart, converts the sunlight into electricity.
- **Inverters:** Convert the direct current (DC) generated by solar panels into alternating current (AC) for use.
- **Mounting Systems:** Structures that hold the solar panels in place, on rooftops, on the ground, or floating on water bodies.

- **Battery Storage:** Stores excess energy generated during the day for use during nighttime or cloudy days, enhancing the reliability of solar power.
- **Racking:** Supports and positions the solar panels.
- **Electrical Components:** Includes wiring, combiner boxes (Gather the output from multiple panels and safely connect it to the inverter.), charge controllers (Manage the flow of electricity to and from the batteries to prevent overcharging.), and transformers, all crucial for directing and managing the electricity flow.

Solar Safety:

Safety is always the highest priority in solar power plants, both in the installation and operational phases. The primary 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

The global community is increasingly adopting sustainable energy solutions, with photovoltaic (PV) systems and renewable energy integration playing a crucial role in this transition. These technologies have the potential to reduce our dependence on fossil fuels and mitigate the impacts of climate change. Successful integration of renewable energy into existing power grids is vital to fully harness the benefits of solar and other renewable sources. This process requires advanced grid management and infrastructure upgrades to address the variability of renewable energy sources such as solar and wind, ensuring a balanced supply and demand. Energy storage solutions, such as batteries and pumped hydro storage, are essential for maintaining a steady energy supply by storing excess energy generated during high production periods and releasing it when production is low. Demand response strategies, involving adjustments in energy consumption based on renewable energy availability, further enhance grid stability and optimize resource utilization. Developing smart grids, incorporating advanced technologies for real-time energy distribution monitoring and management, is critical for improving the efficiency and reliability of renewable energy integration. The effective combination of PV systems and these

integration strategies represents a significant step toward a sustainable energy future, reducing carbon emissions, strengthening energy security, and contributing to a cleaner, greener planet.

2. 3 Design Study of Floating PV Systems

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

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

Water has a cooling effect on solar panels through convection, where moving water carries away heat from the panels, reducing their temperature. The evaporation of water also helps in removing heat as it turns into vapor. Heat transfer from the panels to the water below, known as conduction, also contributes to cooling. As the panels heat up, they transfer heat into the water, aiding in their cooling process. **Additionally**, the panels release heat into the air as they absorb sunlight. This thermal radiation helps in preventing the panels from overheating.

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

The development of floating PV systems encompasses several crucial elements. The buoyant structures that support the solar panels must be engineered to withstand diverse weather conditions and fluctuating water levels. These floating platforms are designed to uphold structural integrity and operational stability. Effective anchoring systems are vital to prevent drifting and to secure the platform's position in relation to the water body. The design and implementation of these anchoring systems present technical challenges that are essential for successful deployment. Furthermore, the durability of the construction materials is of utmost importance, as they must withstand water and environmental elements to ensure long-term performance.

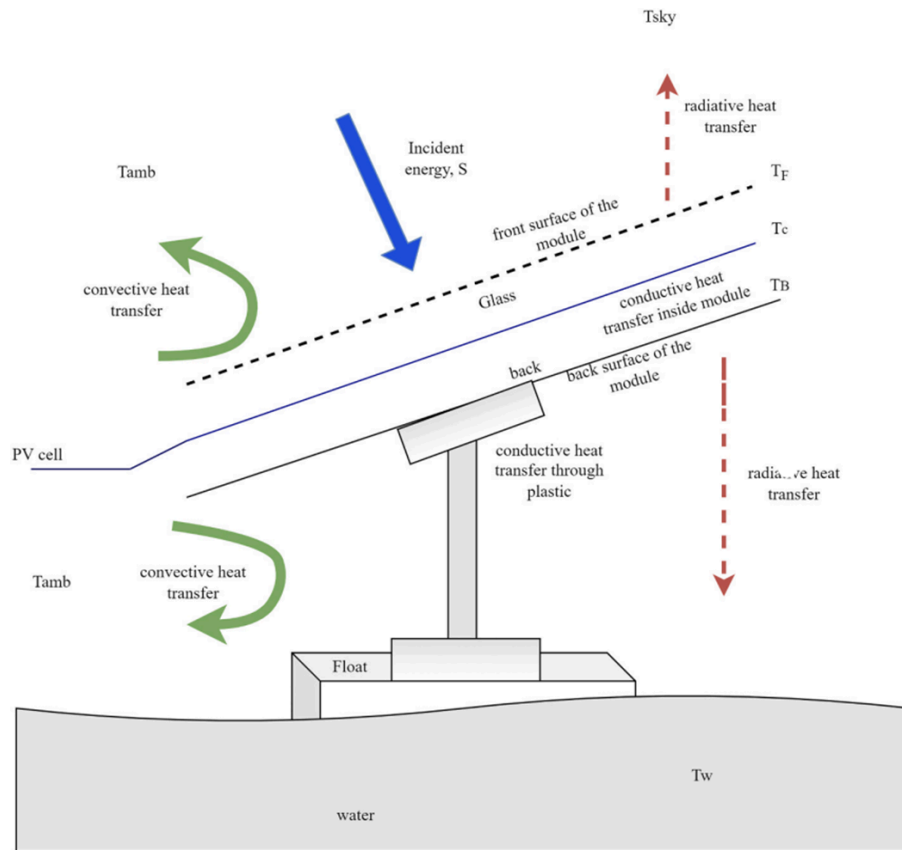


Figure 2: Heat transfer process in FPV

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

The analysis employs the same module and inverter specifications to examine the design parameters for a 1 MW ground-mounted photovoltaic (PV) system and a floating PV system.

The selected module for both systems is the SunPower SPR 314E, combined with the Sungrow Power Supply Co., Ltd. SG125HV [600V] inverter. The design incorporates a DC-to-AC ratio of 1.14, with the array comprising 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 difference 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°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

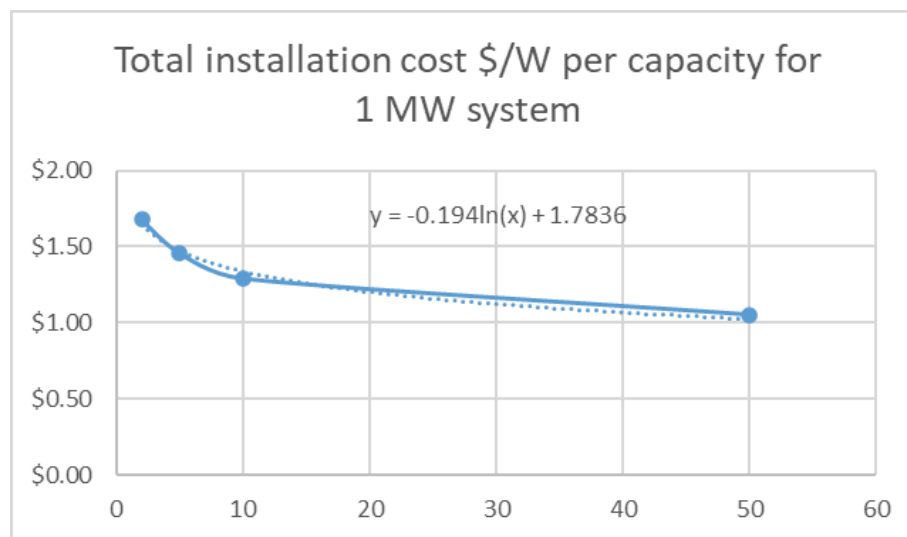


Figure 4: Calculation of total installation cost for 1 MW FPV system_2021

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

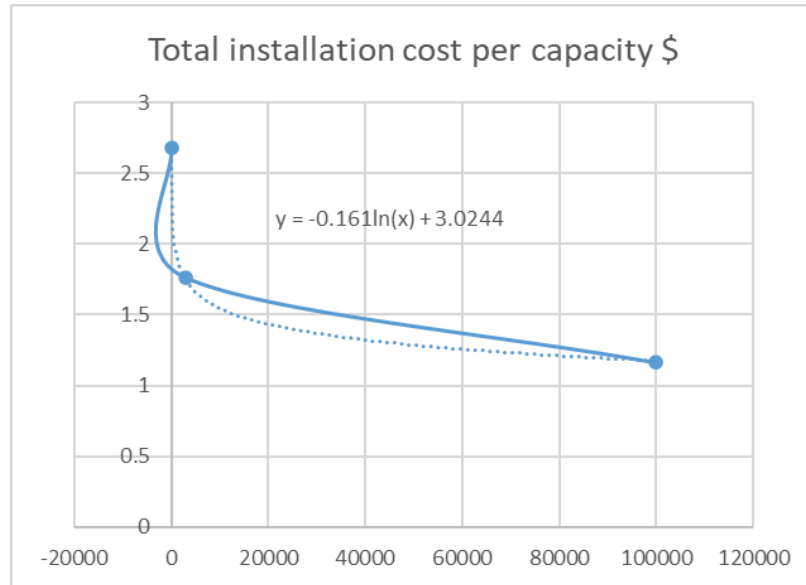


Figure 5: Calculation of total installation cost for 1 MW FPV system

	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 the System Advisor Model (SAM) and PVSyst, are commonly used in the field of PV systems for basic design. Plant Predict is also familiar with this solar energy field, and most importantly, all this software is getting updated day by day to make the design more accurate. This study used the system advisor model's LCOE calculator (FCR method) for design and cost analysis.

2.5.1 System Advisor Model(SAM)

The System Advisor Model™ (SAM™) is a sophisticated desktop application developed for the techno-economic analysis of renewable energy technologies. It was created by the National Renewable Energy Laboratory (NREL) in partnership with Sandia National Laboratories. Initially, SAM was used internally by the U.S. Department of Energy's Solar Energy

Technologies Program and was primarily focused on analyzing advancements in solar technology. The first public version of SAM, released in August 2007, concentrated on photovoltaic (PV) systems and concentrating solar power (CSP) parabolic trough systems.



Over time, SAM has significantly broadened its scope. The model was rebranded as the "System Advisor Model" in 2010 to reflect its expanded capabilities beyond solar technologies. Presently, SAM supports diverse renewable energy systems, such as wind, marine, geothermal, and biomass energy. Its modeling capabilities encompass both technical performance and financial feasibility, providing tailored financial models for various project types, including residential and commercial systems, power purchase agreements (PPAs), and third-party ownership arrangements.

SAM undergoes regular updates, with new versions typically released annually to incorporate the latest technological advancements and financing options. The software has gained widespread adoption, with over 35,000 users globally, including manufacturers, project developers, policy analysts, and researchers. SAM plays a critical role in optimizing renewable energy projects, facilitating informed decision-making, and advancing sustainable energy solutions.

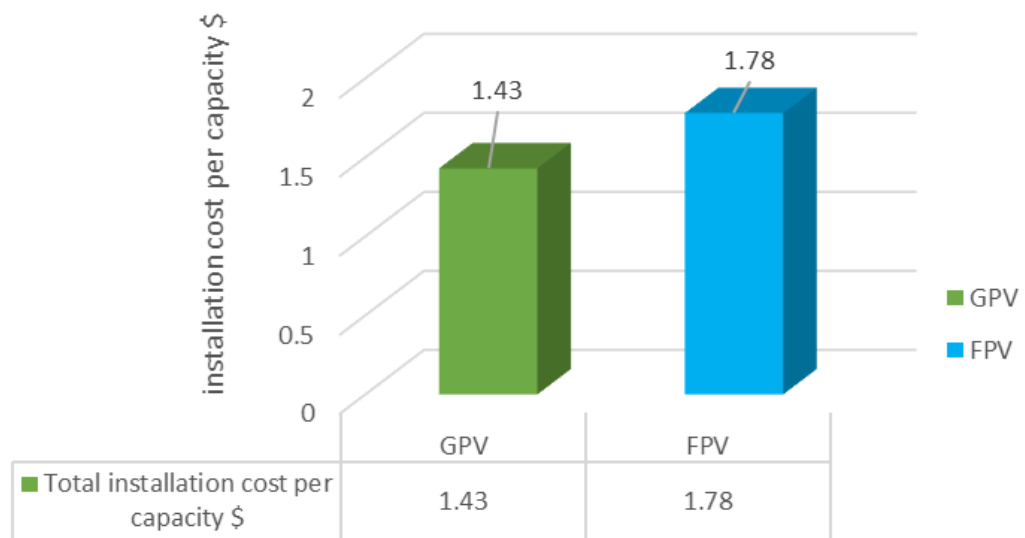
Results and Analysis

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

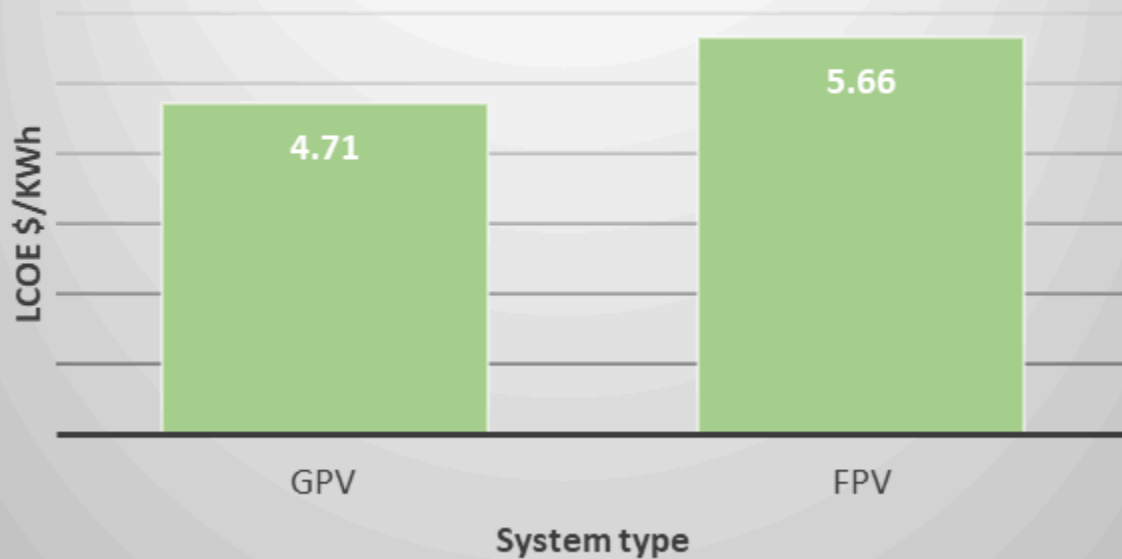


Figure 7: Cost benchmarking for 2021

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.

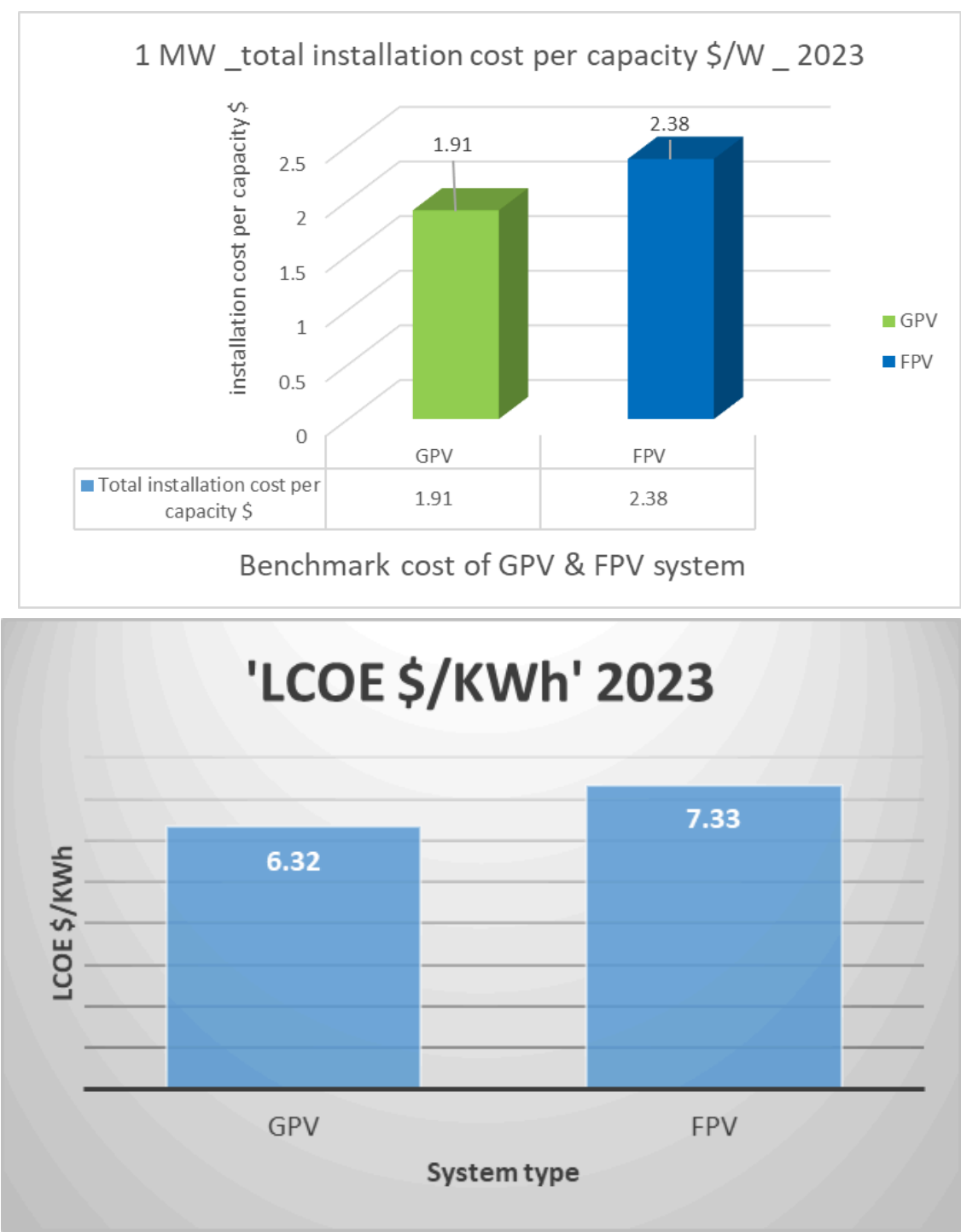


Figure 8: Cost benchmarking for 2023

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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