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NORWEGIAN FLOATING SOLAR PV FACTSHEET

REPORT

Norwegian Floating Solar PV Factsheet

CLIENT

Norwegian Solar Energy Cluster

SUBJECT

Norwegian Floating Solar PV Factsheet

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Foreword

This Norwegian Floating Solar PV Factsheet is designed to present one of the most promising and innovative technologies in the solar energy sector—floating solar photovoltaic (FPV) systems.

Floating solar PV represents a transformative approach to solar energy, allowing for the efficient utilization of water bodies for solar installations without the extensive land use required by traditional ground-mounted systems. This factsheet provides a comprehensive overview of floating solar PV technology, highlighting its benefits such as reduced land use and enhanced energy efficiency due to the cooling effects of water, as well as addressing significant challenges like increased costs and technical demands in maintenance and safety.

With a projected growth rate of 22% and a substantial increase in installed capacity expected by 2031, the FPV sector is on the brink potential significant expansion. This factsheet also aims to inform and guide key stakeholders—including governmental officials, regulatory bodies, transmission operators (TSOs) and distribution system operators (DSOs) through the intricacies of FPV systems.

Additionally, the factsheet serves as a foundational tool for stakeholders to understand the current state and potential of the FPV industry, especially within the Norwegian context, wherein hybrid solutions with hydropower dams and fish farms present unique opportunities. It also explores the broader implications for international development and cooperation, positioning Norway as a potential leader in the global FPV market due to its rich experience in marine and offshore technologies.

By providing this detailed and focused insight, the Norwegian Floating Solar PV Factsheet aims to help inform decision-making, promote sustainable practices, and support the development of policies that will enable the growth of the floating solar industry both in Norway and globally. The anticipated outcome is a more robust, environmentally sustainable, and economically viable solar energy landscape.

Katja Kerschke

Head of Solar FPV/International Affairs

Solenergiklyngen

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APAC	Asia-Pacific	MEA	Middle East-Africa
CAPEX	Captial expenditure	MWp	Mega watt peak
EPC	Engineering, Procurement and Construction	NVE	Norwegian Water Resources and Energy Directorate
FPV	Floating Solar PV	OPEX	Operating expenses
GWp	Giga watt peak	PV	Photovoltaic
IPP	Independent Power Producer	R&D	Research and Development
IRENA	International renewable energy agency	TWh	Tera watt hour
kWp	Kilo watt peak	TWp	Tera watt peak
LATAM	Latin America	Wp	Watt peak
LCOE	Levelized cost of electricity		

Executive Summary

This factsheet examines the Norwegian floating solar PV (FPV) industry within a global framework. It includes insights from interviews with several key stakeholders, providing information on the industry's historical involvement, status, and anticipated developments.

Climate change and land scarcity are significant challenges ahead and FPV offers several benefits that tackles these. With low carbon footprint as well as low land use, FPV plants could become a key solution toward a zero-emission future.

The global FPV market has been growing significantly, with a compound annual growth rate of 37% over the last 5 years, resulting in an estimated total capacity already surpassing 7 GWp worldwide in 2023.

Despite challenges such as regulatory ambiguities and higher costs, the global potential for floating photovoltaic (FPV) systems remains substantial. Norwegian companies and institutions are already key and recognized players in the FPV industry, with their influence expected to expand further. The installed capacity by Norwegian companies has grown fourfold, from less than 1 MWp in 2020 to 3.9 MWp in 2024 and is projected to reach the gigawatt (GWp) scale by 2030. Currently, the Norwegian FPV industry employs over 200 people, with this number anticipated to increase by 50% by 2030. Additionally, several institutions have emerged as leaders in FPV Research & Development, supported by funding from the Research Council of Norway and the European Union.

1 Introduction to Floating Solar PV

Climate change presents one of the most pressing challenges of our time, contributing to increasing temperatures and rising sea levels. Urgent action is imperative. An essential solution lies in reducing emissions through a transition from fossil fuels to renewable energy sources, with solar energy representing a source with vast potential.

While expansion of solar energy to mitigate greenhouse gas emissions from the energy sector is necessary, there is a growing concern regarding the environmental impact of ground-mounted solar parks, particularly concerning land use. Hence, it's important to explore alternative methods of harnessing solar energy in addition to ground-mounted solar PV, and one promising possibility is floating solar PV (FPV). The potential of FPV is significant, with a compound annual growth rate of 37% over the last 5 years, resulting in an estimated total capacity already surpassing 7 GWp worldwide in 2023.

INSEANERGY - NORWAY

FPV plant connected to a fish farm in Norway.
Capacity: 160 kWp
Commissioned: 2024
Inseanergy with technology from Ocean Sun

1.1 Definition and Basic Concept

The general layout and components of a FPV plant, as shown in Figure 1, are somewhat similar to a ground-mounted solar PV system. For most systems, key components (like solar PV modules and inverters) are standard and the same as used in other solar PV applications (ground-mounted or roof-mounted). Main elements that differ from other PV systems are the floats or pontoons that the modules are mounted on as well as the mooring and anchoring system that secures the location of the structure. Cabling to shore can be done with underwater cables or cables mounted on floats.

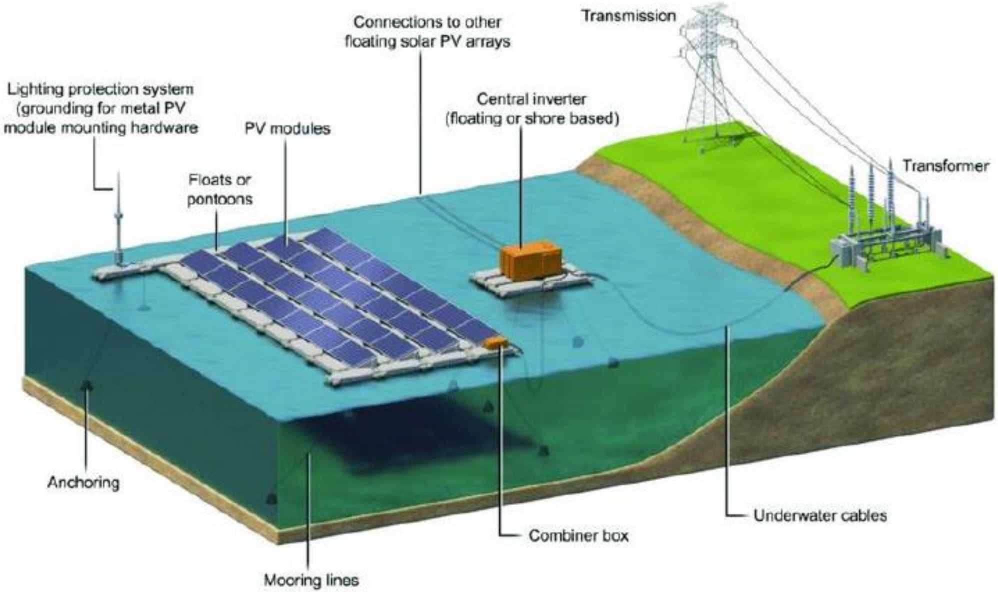

Figure 1: Illustration of a typical FPV system. Source: (Tonnel, et al., 2023).)

Within the field of FPV, there are significant differences related to the type of operational environment. Forces and loads applied to the system (like wind, waves, current, water salinity, water level variation, snow, ice, etc.) can vary significantly from one water body to the other (small pounds or open ocean, for example).

In describing FPV systems, it is therefore helpful to define some different segments. Two natural elements to separate by are wave height and type of water body, as shown in Figure 2.

STATKRAFT & OCEAN SUN - ALBANIA

FPV plant in Banja, Albania.
Demonstration of Ocean Sun technology on a hydropower reservoir.
Capacity: 2 MWp
Commissioned: December 2022.
Ocean Sun for Statkraft

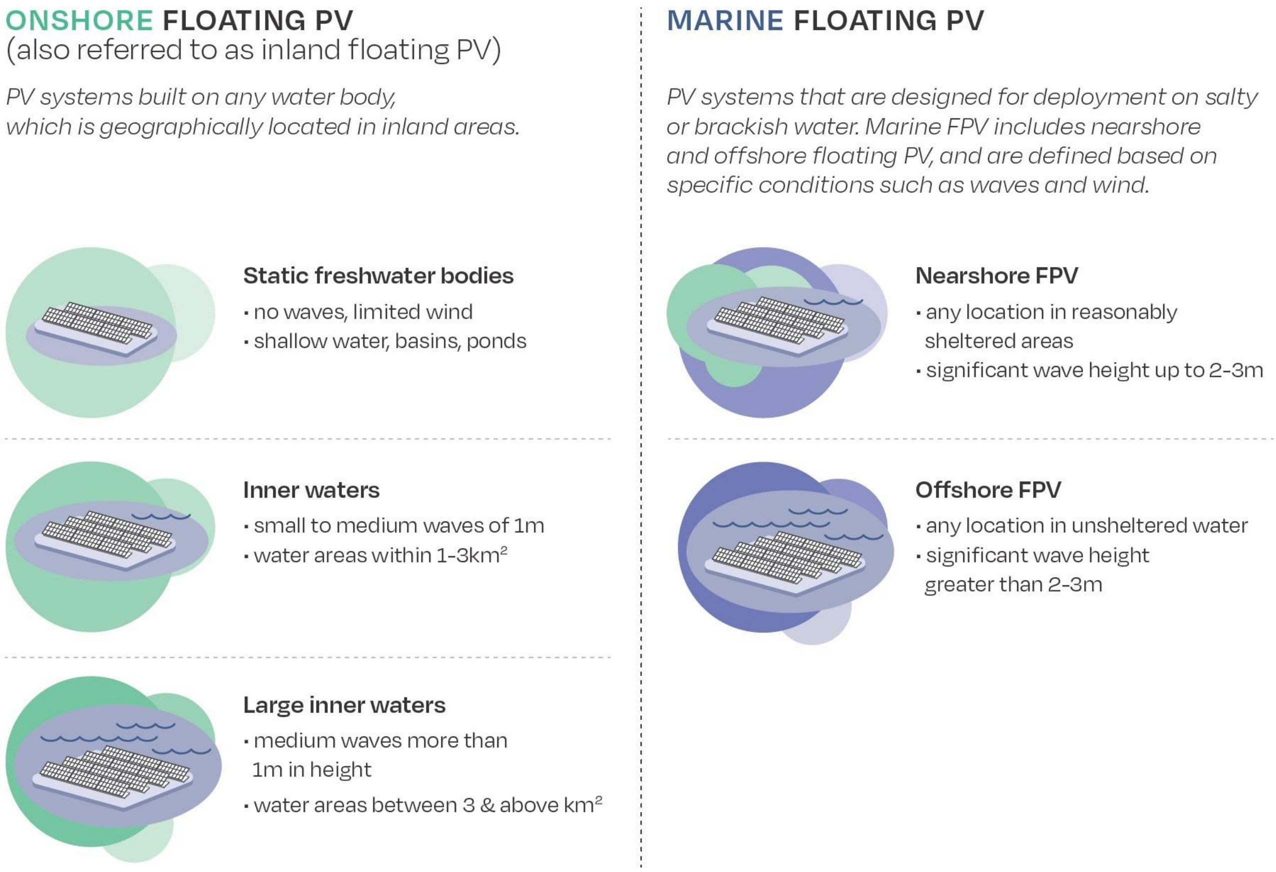

Figure 2: Floating Solar PV Categorization. Source: (SolarPower Europe, 2023).

From the different categories of FPV systems, there are different characteristics and challenges that need to be addressed. For onshore systems deployed on hydropower reservoirs, for example, the water level might change significantly, representing a challenge in designing the mooring system. Offshore solutions need to address significant wave heights and a corrosive environment from salty water. These are just examples of how the onshore and offshore systems differ.

1.2 Main Benefits and Challenges

While the benefits and challenges vary based on the category, there are still several general points that can be made for FPV systems. In 1.2.1 and in 1.2.2 some benefits and challenges are mentioned, while Figure 3 summarizes some of the main ones.

1.2.1 Benefits

Several of the general benefits of FPV are related to the environmental aspects of the installation. The potential reduced use of land area for energy production is an obvious one. With land scarcity, conflict in land use, and more focus on loss of biodiversity, FPV has large benefits. Those benefits also include the **lack of land preparation needed**

FRED OLSEN 1848 - NORWAY

FPV system in Risør, Norway.
Test and demonstration of Fred. Olsen 1848 technology.
Capacity: 124 kWp
Commissioned: 2024

as well as limited effect of fencing that would potentially divide ecosystems. With a uniform water body to install the system on, it follows that the system is **fast and easy to set up**.

Other benefits are related to the lake or water body itself. Since the installation covers part of the water body, it provides shade and then might limit **water evaporation**. This can have a significant impact, especially in warm locations. There are also indications of **reduced algae growth** as well as, in some cases, **improved water quality.**

The PV modules might also benefit from a **cooling effect** from the waterbody it is installed on, leading to **improved yields**.

1.2.2 Challenges

Even though there are several benefits to FPV systems, there are also significant challenges, mainly contributing to increased costs. One of these is the anchoring & mooring system. In addition, an electrical system on water needs to consider both electrical safety and corrosion risks of all equipment. Maintenance of such systems might also be challenging as it might involve the need for divers to do the maintenance.

Another potential negative impact correlating with FPV is the impact of birds. Birds tend to prefer sheltered areas and avoid human or predator disturbance, and FPV systems might be considered an attractive location. Their droppings might in turn increase soiling losses. Even though FPV systems might impact positively the water body's environment, the reduced light penetrating water might also have a negative impact on fauna and flora.

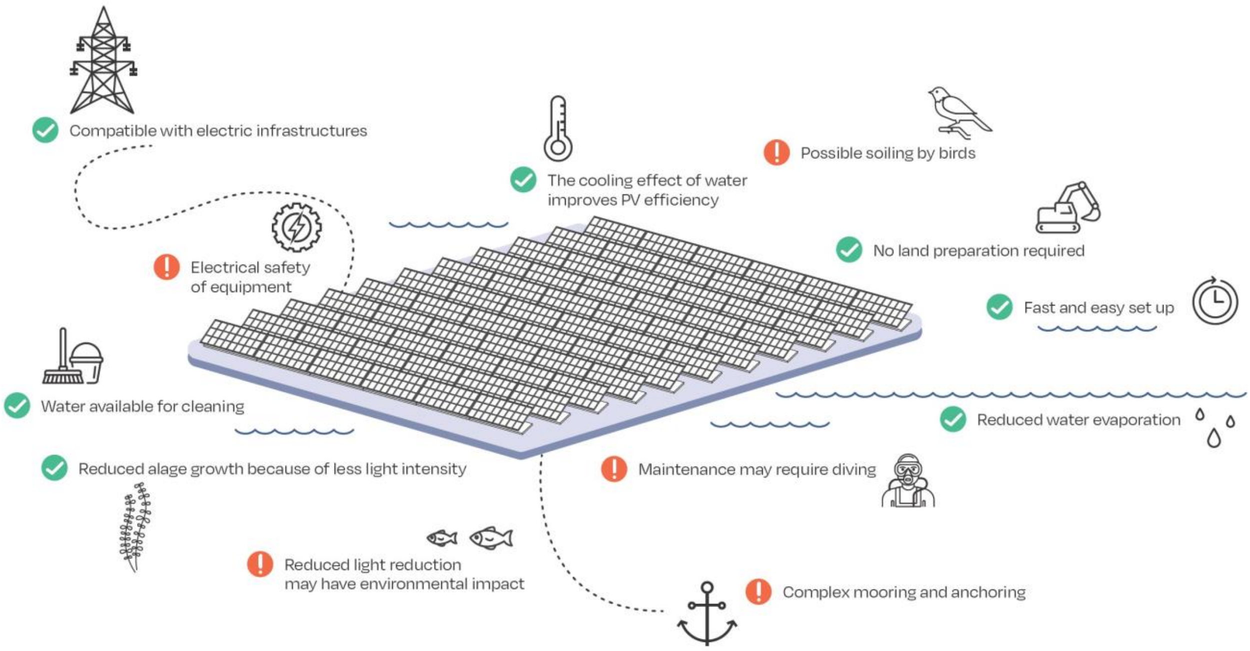

Figure 3: Overview of the Potential Benefits and Challenges of Floating Solar PV. Source: (Pouran, Lopes, Nogueira, Branco, & Sheng, 2022) & (SolarPower Europe, 2023)

2 Global Market

As shown in Figure 4, the FPV market has been growing significantly, with a compound annual growth rate of 37% over the last 5 years, resulting in an estimated total capacity already surpassing 7 GWp worldwide in 2023.

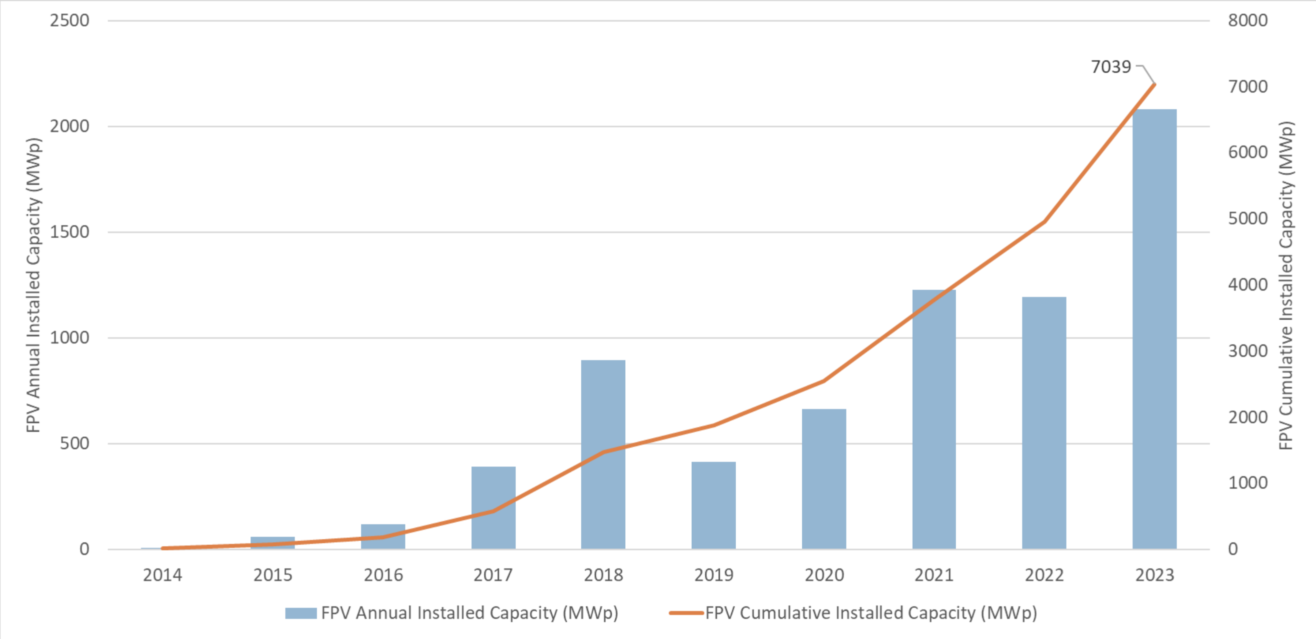

Figure 4: FPV annual and cumulative capacity between 2014 and 2023. Source: Ciel et Terre.

So far, FPV installations has mainly been in the Asia-Pacific (APAC) region as seen in Figure 5. There is some uncertainty regarding where future FPV systems will be installed, but areas with scarcity of land and high population have increased incentives for FPV.

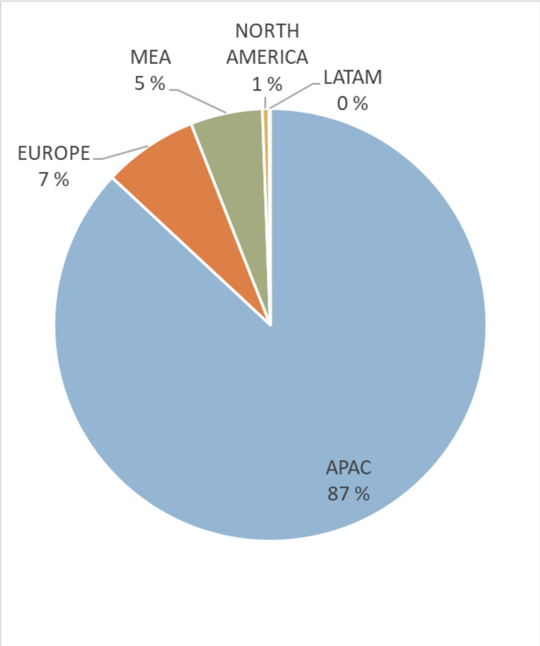

Figure 5: FPV cumulative installed capacity in 2023 by region. Source: Ciel et Terre.

Since 2018, Europe has shown significant growth, reaching 500 MWp of installed capacity in 2023 and representing 7% of the global installed capacity (second biggest market after APAC), as shown in Figure 6.

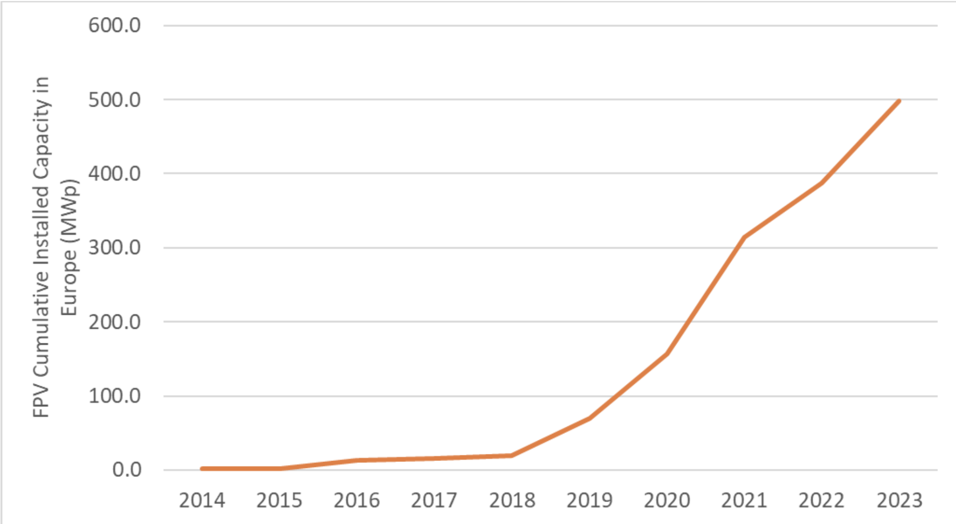

Figure 6: FPV cumulative installed capacity in Europe between 2014 and 2023. Source: Ciel et Terre.

3 Economic Considerations

The international renewable energy (IRENA) evaluates the cost of renewable energy by source each year. For solar energy, their results include a reduction in installed cost from 2021 to 2022 of 4% while the reduction for levelized cost of electricity (LCOE) in the same period was 3%. If we look at a longer time period, the reduction since 2010 has been of 89 % for LCOE. One of the main drivers has been the reduction in PV modules price, that in Europe has declined by 91% from 2009 to 2022 (IRENA, 2023). The cost developments from 2010 can be seen below in Figure 7. Another key driver for this cost reduction is the installation rate. From 2010 to 2022 there has been a 26-fold growth. The yearly installation rate also increased by 36 % from 2021 to 2022 (IRENA, 2023).

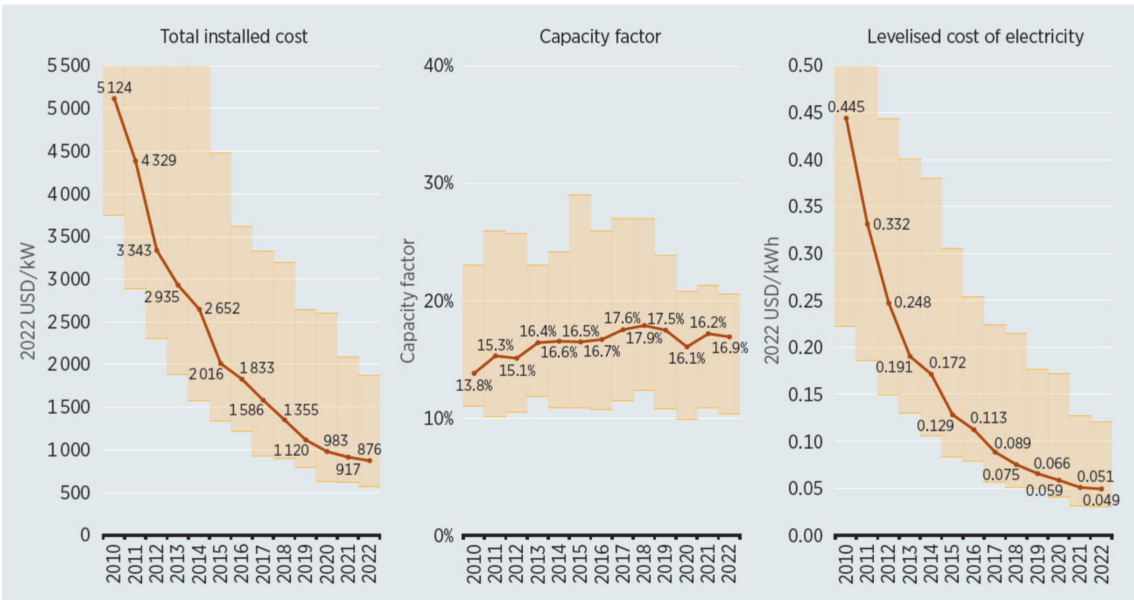

Figure 7: Cost development for ground-mounted PV from 2010 to 2022. Source: (IRENA, 2023).

From 2018 to 2020, in the US, OPEX ranged between 11 USD/kW/year to 20 USD/kW/year (Boiling, 2022). OPEX in Europe is at average 10 USD/kW/year (Steffen, 2019).

While installation rates for ground-mounted PV have increased significantly, the FPV rates are still comparably low. The accumulated installed capacity for FPV was 7 GWp in 2023, representing less than 1% of the 1,047 GWp of total solar PV capacity deployed worldwide. CAPEX for onshore FPV installations can in many cases be up to 10-15% more than the ground-mounted benchmark. This premium is mainly linked to the cost of floats, anchoring and mooring and can vary significantly according to the site and environment. The offshore FPV market is still somewhat early in the demonstration phase. Current associated costs are not representative of what the segment might become in coming years and significant cost reductions will come with deployment.

SOLARDUCK - NETHERLANDS

FPV plant in Merganser, Netherlands.
Offshore floating solar demonstrator plant
Capacity: 520 kWp
Built but not commissioned yet.

Beyond economics, FPV can often provide advantages that are harder to quantify, as mentioned in Chapter 1.2.1, like avoiding land use conflicts, improving water quality, reducing water evaporation, etc.

4 Policy and Regulatory Overview in Europe

When considering the policy and regulations for FPV, it is important to keep in mind that there are large variations from country to country and that the industry is still in a quite early phase. One of the challenges is the lack of standardization at regional level (EU, for example). Furthermore, obtaining permits for water use can be challenging, as FPV systems are often installed on reservoirs, lakes, and other water bodies with existing legal frameworks for water rights. These permits are usually governed by multiple authorities, adding to the complexity and impacting both costs and implementation time. FPV systems must also comply with regulations to ensure they do not obstruct navigation, compromise water safety, or interfere with other uses of the water body, such as fishing and recreation. These requirements can vary widely across regions.

Many European countries lack a dedicated regulatory framework for FPV, often treating it under general solar PV regulations, which may not address the unique aspects of floating installations.

Some countries in Europe, however, have issued regulation specific to FPV. For example, some have specified a maximum coverage of water bodies by FPV installations (Germany: 15%, Greece: 10%, Emilia-Romagna region of Italy: 70%). Germany also requires a minimum of 40 meters from shore.

Since FPV systems have a higher cost than ground-mounted PV, but experience less land-use conflicts, some countries have drafted different support and subsidy schemes. Some focus on separate tenders for FPV (like Italy, or plans in Germany) or higher environmental score for FPV in public tenders (France), while others use direct subsidies (Netherlands, Belgium) or discounted calculations in tariffs ceilings (Austria) (SolarPower Europe, 2024).

A simplified, standardized and clearly defined regulatory framework is needed at country or region level to enable sustainable growth of the FPV industry.

5 The Norwegian Floating Solar PV Industry

5.1 Floating Solar PV in Norway

The Norwegian government has a goal to produce 8 TWh of solar PV per year by 2030. The market is currently driven by rooftop installations, both on private households and on commercial and industrial buildings, but the ground-mounted segment is emerging, with a significant capacity waiting for concession approval. In 2023, the accumulated installed capacity surpassed 600 MW, half of which was installed during 2023. The total capacity in concession queue for ground-mounted systems stands at 1,084 MWp.

As snow loads and ice increase the costs of FPV systems, the Norwegian Nordic climate conditions are in general not optimal. However, there is a large potential for several specialized cases, like the combination with fish farms, the hybridization of hydropower (representing 90% of the Norwegian power generation), or the co-location with offshore wind. Although the potential is significant, there is uncertainty regarding the regulatory framework now and in the future.

SCATEC & OCEAN SUN - PHILIPPINES

FPV plant in Magat, Philippines.
Demonstration of Ocean Sun technology on a hydropower reservoir.
Capacity: 250 kWp
Commissioned: June 2019
Ocean Sun for SN Aboitiz Power & Scatec

Some FPV pilots have been deployed in Norway by Ocean Sun (6.6 kWp and 100 kWp on the west coast, decommissioned), Sunlit Sea (105 kWp in Trondheim), Inseanergy (160 kWp in Møre og Romsdal), Fred Olsen 1848 (124 kWp in Risør) and Moss Maritime (30 kWp in Trøndelag), currently in construction.

OCEAN SUN - CHINA

FPV system in Haiyang, China.
R&D project in the yellow sea with wind turbines
Capacity: 500 kWp
Commissioned: October, 2022

5.2 Export and International Developments

The potential for FPV globally is significant. Man-made reservoirs represent more than 400,000 km^2 surface area available. By covering 10% of their surface, the global potential installation capacity exceeds 4 TWp, corresponding to a yearly production potential of about 5,200 TWh (World Bank Group, ESMAP and SERIS, 2019).

With its long coastline and many inland water bodies, Norway's industrial history is inherently linked to water. The hydropower, offshore and marine industries have over many decades built significant competence that can be applied to the floating solar PV segment, and the country is already well represented in the global pool of FPV systems providers.

5.2.1 Actors, Market Segmentation and Geography

The table below presents different actors from Norway that are working with FPV in different aspects. Given information is collected from interviews as well as publicly available information.

Name	Logo	Participated in consultations	Type	Introduction	History	Offices/Location	Provides
DNV	DNV	Yes	Consultant	Founded in 1864 by a group of marine insurance clubs. Now holds offices in more than 100 countries and has 14,500 employees	Started with FPV in 2017 in the Netherlands. Used their maritime knowledge to develop FPV competence.	For FPV related tasks: Netherlands, Singapore, Oslo, France, Italy, Montreal, Houston	Consultancy services for all parts of the FPV industry.
Equinor	equinor	No	Independent Power Producer	Founded in 1972 by the Norwegian Government to manage the country's oil and gas resources	Collaboration initiated with Moss Maritime with regards to FPV pilot in 2019.	Equinor is present in over 30 countries around the world	Project developer and possible investor.
FredOlsen 1848	Fred. Olsen 1848	Yes	Technology provider	Founded in 2022 with the focus on technology development within renewable energy nearshore and offshore.	Started with FPV in 2018 because of lack of solutions for their need. The idea for FPV technology Brizo in 2021.	Oslo, Aarhus and Manila	Cost effective solutions for near shore.
IFE	IFE	Yes	Research Institute	Established in 1948 with focus on nuclear energy. Later transitioned to energy research	Started with FPV in 2016. Separate research group for FPV in 2021.	Oslo	Research in O & M analytics, thermal modelling and reliability.
Inseanergy	inseanergy Green leadership	Yes	Independent Power Producer	Founded in 2020. Background within submerged PV modules	Hands on approach towards FPV tailored towards fish farms.	Ålesund, Norway	Turnkey solutions focused primarily on fish farms.
Moss Maritime		Yes	Technology provider	Founded in 1973 with focus on LNG carrier.	Started with FPV in 2017 based on their maritime competence.	Oslo	Turnkey solutions that can be adapted to customers need.
Multiconsult	Multiconsult	Yes	Consultant	Founded in 1908 within hydropower and environment.	Focus on FPV started in 2016. Close relationship with Norwegian FPV industry through projects and research.	For FPV related tasks: Oslo	Market studies, system design, hybridization

					FPV projects worldwide (focus on Africa).		and project procurement services.
Ocean Sun		Yes	Technology provider	Founded in 2016 with focus towards hydro dams	Patented solution developed with hydroelastic membrane.	Norway, China, Singapore	Solution with direct cooling and documented higher efficiency for onshore/near shore.
Scatec		No	Independent Power Producer	Founded in 2007 with focus on large scale solar PV plants	Has been involved in several FPV projects, including the Magat project in collaboration with Ocean Sun.	Oslo (headquarters), 16 countries around the globe	Project developer and possible investor.
SINTEF		No	Research Institute	Founded in 1950 to promote technological and other types of industrially oriented research	Has been involved with several Norwegian FPV technology providers to test different solutions.	Trondheim, Oslo	Research in different impacts on FPV systems including wave and other marine elements.
Solar Duck		Yes	Technology provider	Founded in 2019 with engineers from maritime sector	Experience from maritime sector used to design system for offshore application from the start.	Rotterdam, Oslo, Tokyo	A design made from scratch for offshore application.
Statkraft		No	Independent Power Producer	Founded in 1895 with building and owning hydropower plants. Is Europe's largest generator of renewable energy	Focus on possibilities regarding hybridization with hydro dams. Owns and operates the FPV plant in Banja with technology from Ocean Sun.	Oslo (headquarters), several locations around the world.	Project developer and possible investor. Also involved in R&D projects.
Sunlit Sea		Yes	Technology provider	Founded in 2019 with focus on R&D as well as developing unique and robust patent	Idea for cheaper and more effective FPV solution than available in the market.	Oslo, Wolverhampton	System with low price, simple logistics and installation as well as robust floats.
Svalin Solar		Yes	Technology provider	Founded in 2017 with focus on developing concept	Idea for FPV system with low footprint by using concentrated solar.	Stavanger	System with low material use where large parts can be recycled.

While the FPV industry has been significantly expanding the last years, several Norwegian companies already started FPV activities in 2016 and 2017. While the mentioned companies started in Norway, several of them have an international presence. In addition, most companies and institutions are involved in projects around the globe, as shown in Figure 8, including projects in The Netherlands, Spain, Albania, Singapore, The Philippines, China and Japan.

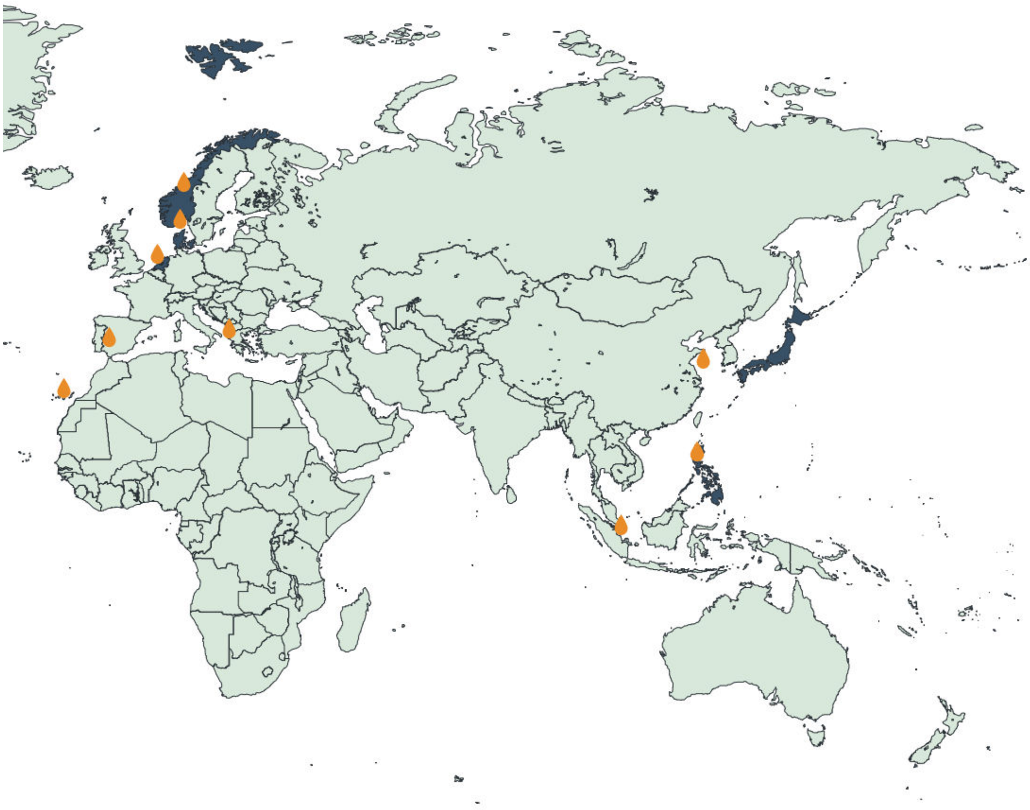

Figure 8: Map of Norwegian FPV implantations/offices (in blue) and projects (orange points), excluding consultancies and R&D institutions.

5.2.2 *Competitive Edge, Volumes and Job Creations*

From the middle of the 19th century, Norway was established as one of the marine headquarters of the world and was in 1875 the third largest sea faring nation. Around 100 years later, oil was found on the Norwegian continental shelf and, around the same time, the Norwegian fish farming industry boomed. This backstory is part of the history of several of the Norwegian companies involved in floating PV today.

The history and competitive edge for Norwegian companies is therefore based on their extensive knowledge within fish farms, general marine fields as well as offshore technology.

While Norwegian companies and institutions employed around 80 people dedicated to FPV in 2020, by 2024 this number had doubled (excluding consultancy firms). Estimates for 2030, based on interviews with key players, are another 50 % increase, as shown in Figure 9.

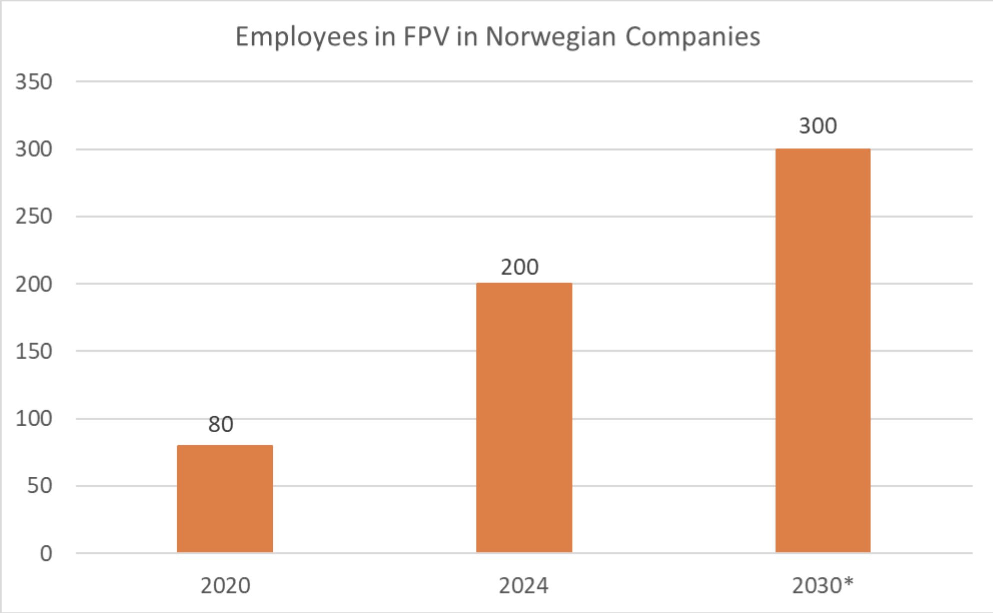

*Figure 9: Employees within FPV in Norwegian companies excluding consultancy firms. *: Numbers and projection for 2030 based on interviews with market players.*

Capacity installed from Norwegian players has increased 4 times from 2020 (less than 1 MWp) to 2024 (3.9 MWp). And while expectations for 2030 are unsure, several companies are looking into GW-scale within that time frame, as can be seen in Figure 10.

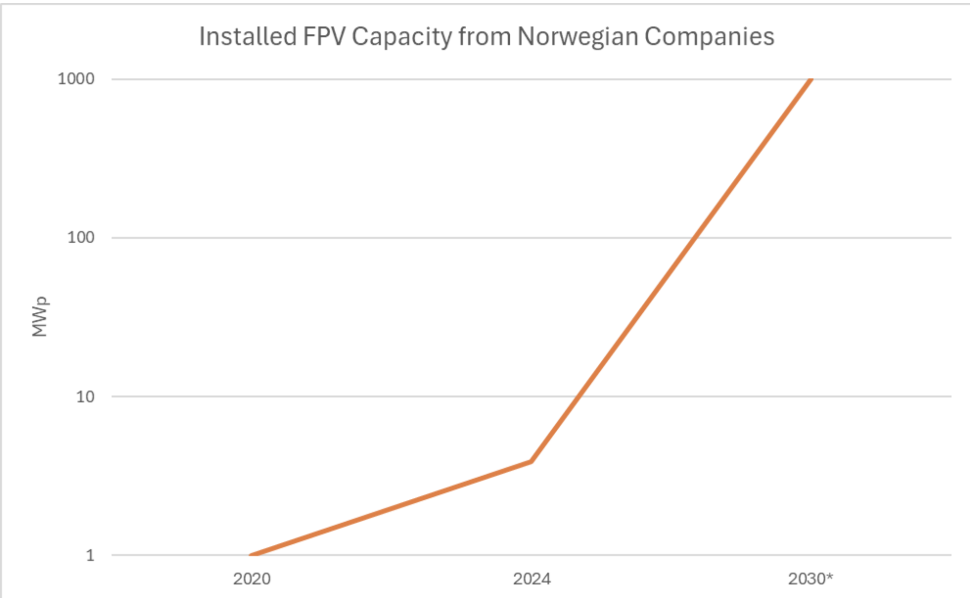

*Figure 10: Accumulated installed capacity from Norwegian companies in MWp, with projections for 2030. *: Numbers based on interviews with market players.*

The identified Norwegian Research and Development institutions active in FPV have managed to successfully establish their reputation in the industry by managing or being involved in several international projects and publications covering important topics like wave resistance, floats design and anchoring & mooring design (SINTEF), as well as thermal modelling of FPV, yield assessments and reliability (IFE). Norwegian consultancies like DNV and Multiconsult are massively involved in Norwegian and international FPV projects, participating in improving business development and risk management by providing services like technical support, feasibility studies and construction supervision. DNV, for example, has been leading global standardization efforts by providing recommended practices dedicated to FPV (DNV, 2021) and developing industry standards for floats and anchoring & mooring, while Multiconsult has provided technical support to many Norwegian technology providers and is involved in several FPV project with development finance institutions on the African continent.

6 Conclusion and Perspectives

As presented in the introductory chapter there are several benefits and challenges for FPV systems. While some of them can be solved with technological advances, some might need project-based adaptation.

With the global FPV industry in an early stage and few projects built there are significant challenges regarding regulation and standardization. Few countries have developed a clear framework, and many governmental bodies are usually involved. There are also few standards available within the FPV sector.

The potential for FPV systems on the other hand stands significant at 4 TWp if only manmade reservoirs are included. This is contrasted by the accumulated installed capacity of just 7 GWp.

Norwegian market players are already heavily involved in the FPV industry and provides both R&D, new innovative systems as well as project development. With long and extensive knowledge and experience within the maritime, offshore and aquaculture sectors, Norwegian companies are contributing strongly to the development of the FPV industry.

Among interviewed players there are significant plans for growth and expansion. While the installed capacity is expected to go from MWp-scale to a GWp-scale, job creation is expected to increase by 50% towards 2030.

SUNLIT SEA - GERMANY

FPV system in Mannheim, Germany.
Demonstration of Sunlit Sea technology in a waterpark.
Capacity: 60 kWp
Commissioned: August 2023
Sunlit Sea for Rixen Cableway

References

Boiling, M. e. (2022). *Utility-Scale Solar, 2022 Edition.* LBNL.

DNV. (2021). *Recomended Practice DNVGL-RP-0584 Design, development and operation of floating solar photovoltaic systems.*

IRENA. (2023). *Renewable power generation costs in 2022.* Abu Dhabi: International Renewable Energy Agency.

Pouran, H. M., Lopes, M. P., Nogueira, T., Branco, D. A., & Sheng, Y. (2022, November 18). Environmental and technical impacts of floating photovoltaic plants as an emerging clean energy technology. *iScience*. doi:https://doi.org/10.1016/j.isci.2022.105253

SolarPower Europe. (2023). *Floating PV Best Practice Guidelines Version 1.0.*

SolarPower Europe. (2024). *Recommendations on onshore Floating PV.* Brussels: SolarPower Europe.

Steffen, B. e. (2019). *Experience Curves for Operations and Maintenance Costs of Renewable Energy.* Joule, vol. 4/2, pp. 359–75.

Tonnel, S., Ikhennicheu, M., Failler, R. L., Gorintin, F., Varbaro, U., Moya, A. A., & Ziar, H. (2023). *Guidelines for design, procurement and O&M friendly concepts for floating PV.* Trust-PV.

World Bank Group, ESMAP and SERIS. (2019). *Where Sun Meets Water: Floating Solar Market.* Washington, DC: World Bank.