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EMERGING TECH RESEARCH

Floating Wind and Solar Energy

Floating wind and solar energy technologies provide unique benefits in certain applications

PitchBook is a Morningstar company providing the most comprehensive, most accurate, and hard-to-find data for professionals doing business in the private markets.

Key takeaways

- The VC ecosystem for floating wind and solar technologies is small, driven by a historically higher focus on fixed implementations and the immaturity of floating platform technologies designed specifically for renewable energy. However, global interest in these technologies is increasing, and the varied applications for floating renewable energy provide opportunities for companies in this space.

- Floating wind technologies focus on offshore, deep-water implementations, but differences in local conditions, such as water depth, wave height, and seabed composition, affect the viability of different technologies. No single approach is more effective than others. Floating solar, which generally leans more toward inshore, artificial water bodies, is also varied, with multiple applications, including municipal and industrial reservoirs and the aquaculture industry.

- Floating wind and solar technologies face some significant challenges that are largely based on the cost premium relative to fixed designs but also on technical difficulties with floating platforms and grid connections. Price differentials between floating and fixed technologies are predicted to decrease as the technologies mature—US estimates show a price premium of approximately 25% for floating solar projects relative to fixed solar projects.[1] In the US, floating wind is estimated to have a significant price premium of 176% over fixed-bottom offshore wind, though this is expected to decrease considerably by 2035 to just 21%.[2]

- Floating renewable energy technologies also provide a set of benefits, including reduced land use; access to areas with stronger, more stable wind (in the case of floating offshore wind); and reduced water loss from reservoirs (in the case of floating solar installations).

1: "Floating Photovoltaic System Cost Benchmark: Q1 2021 Installations on Artificial Water Bodies," National Renewable Energy Laboratory, Vignesh Ramasamy and Robert Margolis, October 2021.
2: "A Driving FORCE for Projecting Offshore Wind Energy Costs," Department of Energy, April 13, 2023.

Floating wind and solar energy VC ecosystem

The floating wind and solar industries are still small relative to both terrestrial and fixed-bottom offshore wind and solar industries. Currently, many of the largest installations have been built by utilities such as Portugal's EDP or by large public companies that focus on energy and often have significant historic activity in the oil & gas sector. The core technical challenge for floating solar and wind technology providers lies in the floating platform, as the electricity-generating components they support are often sourced externally. Most of the startups in this space follow this approach, developing floating platforms themselves and then choosing appropriate turbines or solar panels on these platforms. The startup ecosystem is very small at present due to the cost premiums of floating technology relative to fixed-base installations and limited demand, but interest is increasing in key regions, driven by emissions targets and wider acknowledgment of the importance of energy independence and resilience.

VC-backed companies focusing on floating energy are fairly evenly split between the wind and solar categories, and Europe accounts for more than 50% of companies in both categories. VC deal sizes tend to be somewhat low, with Principle Power's $20.0 million early-stage VC deal and $22.0 million late-stage VC deal being the largest. Considering the size of the VC-backed floating wind and solar space, few exits have been seen. In 2021, France-headquartered floating wind technology developer Ideol was acquired by Norway-based offshore wind company BW Offshore and went public as BW Ideol via IPO shortly after, raising $67.6 million. BW Ideol uses a barge-type platform with a damping pool for stability and has operating projects in both France and Japan. Other European projects are in progress, including a partnership to develop approximately 1 GW of floating wind energy as part of the Buchan Offshore Wind project off Scotland's northern coast. Hexicon is a Sweden-based developer of floating wind technology and raised $41.4 million via IPO in 2021 after several rounds of VC funding. The company has also been expanding its project portfolio in Europe, with particularly strong development in Italy and Sweden. Hexicon uses a multi-turbine approach, with two turbines on a semi-submersible or a tension leg platform (TLP), depending on site conditions.

The US has particularly strong potential for floating solar growth due to its high number of viable sites.

Floating wind and solar represent an opportunity for startups. The space has few market participants, and several key regions, including the US, EU, and UK, have announced growth in renewable energy sources, including specific growth targets for floating energy. Europe and Asia have already begun to increase installed capacity, and the US has held auctions for the first floating offshore wind leases. These leases included five sites off the coast of California, four of which were won by European companies. Further auctions for sites in Oregon and Maine are expected in 2024. Policy support is driving adoption in several geographies, and interest in energy resilience is also a key driver. Floating solar startups are varied in their approaches and target applications, including municipal and industrial reservoirs and aquaculture. The US has particularly strong potential for floating solar growth due to its high number of viable sites.[3]

3: "Energy Production and Water Savings From Floating Solar Photovoltaics on Global Reservoirs," Nature Sustainability, Yubin Jin, et al., March 13, 2023.

Technologies for floating platforms are highly varied, and the most suitable technology will depend on the use case. Startups tend to focus on a single design, and this provides space for a diverse range of approaches in floating wind and solar markets. Since floating platforms' energy generation technology is typically from third parties, startups developing floating platforms are potential targets for partnerships or acquisition to expand the offerings of companies providing renewable energy hardware or fixed-bottom renewable projects.

The need for floating energy

Clean energy efforts have been growing globally as nations have announced climate goals and the cost of low-carbon energy technologies has fallen. Additionally, recent geopolitical events have highlighted the importance of energy security, which renewable energy can provide. In some situations, the levelized cost of energy (LCOE) for renewable energy technologies is now cost-competitive with conventional fossil-fuel-based approaches, and utility-scale solar and wind energy are among the cheapest options, particularly when taking government subsidies into account.[4, 5] For both solar- and wind-based electricity generation, total costs vary greatly depending on factors such as the local climate, existing connections to power grids, land costs, and materials costs. Of these, utility-scale terrestrial installations generally have the lowest LCOE. Interest in community and residential renewable energy has increased, but these applications have a much higher LCOE relative to large-scale installations.

Though terrestrial installations represent the lowest cost of all wind and solar projects, there is also a growing desire for water installations—particularly for offshore wind projects. Although they have a slightly higher LCOE, these installations contend less with aesthetic problems and higher land costs. Existing designs for fixed-bottom offshore wind technology allow wind farms to be constructed in water up to a depth of about 200 feet, which provides plenty of additional sites for regions that have substantial continental shelf, but in locations where water depth increases more rapidly, offshore wind must rely on floating technologies.

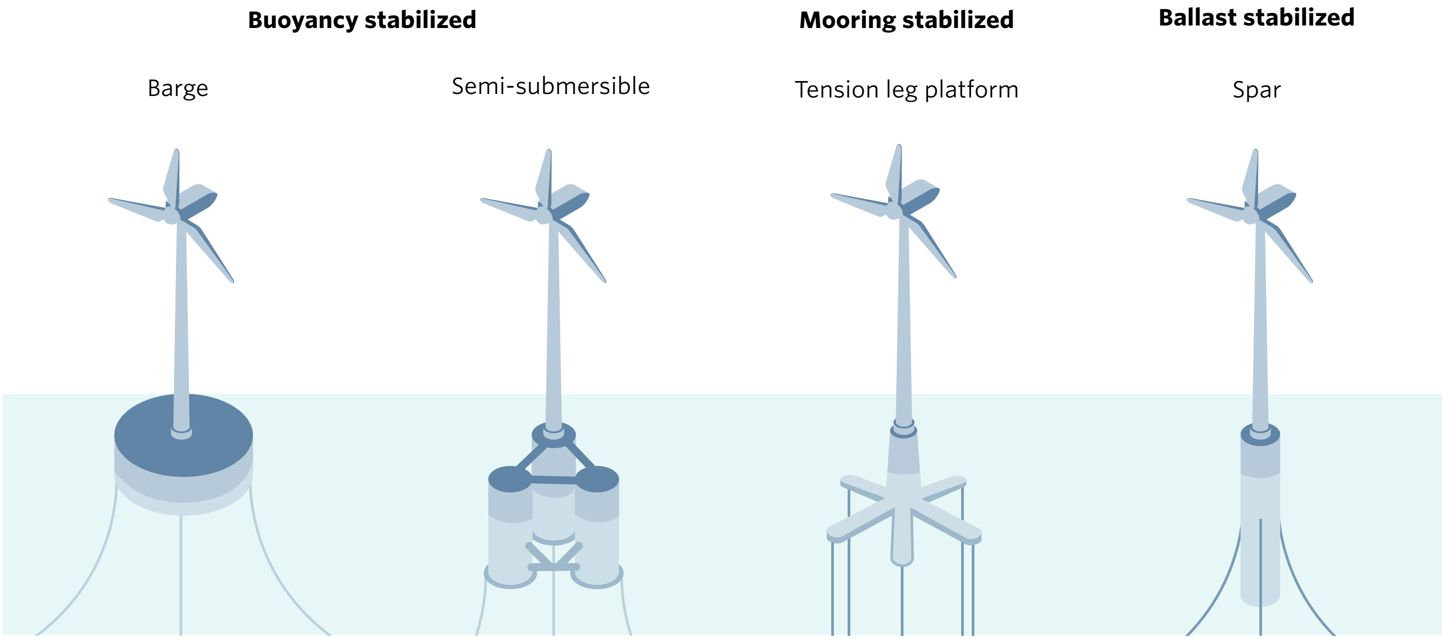
Floating platforms have a long history in the oil & gas industry for exploration and production purposes, and the development of these technologies forms the basis of floating offshore wind turbine (FOWT) designs, which are often separated by their stabilization method:[6]

4: LCOE is a measure of the average cost of electricity generation over the installation's lifetime, including initial capital costs, operation and maintenance, and fuel costs, where appropriate. Essentially, LCOE is equal to the sum of costs over the asset's lifetime, divided by the total electricity generated.
5: "Lazard's Levelized Cost of Energy Analysis—Version 16.0," Lazard, April 2023.
6: "Critical Review of Floating Support Structures for Offshore Wind Farm Deployment," Journal of Physics: Conference Series, Mareike Leimeister, et al., 2018.

- **Buoyancy-stabilized platforms**, with a relatively wide cross-sectional area at the water plane and a shallow draft, can be used in shallower water and also allow for construction and maintenance in a port. These designs can consist of barge-style platforms or of semi-submersibles with several floating pontoons attached to each other.

- **Ballast-stabilized platforms**, often referred to as spar platforms, use deep draft designs with ballast at the base. This offers good stability and reduces movement due to waves but requires deeper water and can cause transport and installation challenges.

- **Mooring-stabilized platforms** use TLP designs, which differ from other designs in that their mooring lines are under constant tension from the buoyancy of the submerged platform. The submerged platform allows a small waterplane cross section, giving additional stability, but the installation challenges are more significant, particularly with mooring lines.



Sources: PitchBook and Electronics, derived from Creative Commons

In the US, FOWTs are a recent development, with the first auctions for FOWT sites concluding at the end of 2022. Of the five winning bids, PE-backed Invenergy was the only US-based winner. The US has announced plans to accelerate its adoption of floating offshore wind alongside fixed-bottom offshore wind.[7] While the Department of Energy calculates that the average LCOE for floating offshore wind is substantially higher than fixed-bottom offshore wind ($207/MWh for floating versus $75/MWh for fixed in 2021), it expects the maturation of the technology to greatly reduce this gap by 2035 ($64/MWh for floating versus $53/MWh for fixed).[8]

7: "U.S. Department of Energy Announces New Actions to Accelerate U.S. Floating Offshore Wind Deployment," Department of Energy, February 22, 2023.
8: "A Driving FORCE for Projecting Offshore Wind Energy Costs," Department of Energy, April 13, 2023.

Currently, floating solar energy fills a somewhat different role from FOWTs. It is usually applied at smaller scales and often on artificial water bodies, such as reservoirs and canals. It is used either for additional power generation or to supplement nearby energy consumption and tends to have different engineering requirements from floating wind platforms because of the different water conditions that floating solar and floating wind are applied to. The much smaller surface area of floating solar technology also simplifies the requirements of the platforms.

Geographical differences

Overall interest in large-scale adoption and development of floating wind and solar energy has emerged only relatively recently, though some geographies are further along in implementing floating energy technology. In general, Europe and Asia are more advanced, with large-scale projects including:

- **Hywind Scotland**: The world's first commercial floating offshore wind farm involves five 6-MW FOWTs on floating spar platforms for a total capacity of 30 MW. The project is a joint venture between Norwegian energy company Equinor and United Arab Emirates-based energy company Masdar.
- **Hywind Tampen**: Currently under construction by Equinor, this will be the largest floating offshore wind farm once operational, consisting of 11 FOWTs on floating spar platforms with a total capacity of 60 MW. The project will be used to provide clean energy to nearby offshore oil and gas fields.
- **Kincardine Offshore Wind Farm**: The largest currently operational floating offshore wind farm, Kincardine is located 15 kilometers off the coast of Scotland and consists of five Vestas turbines on semi-submersible floating platforms built by Principle Power.
- **Alqueva floating solar power plant**: This 5-MW floating solar power plant in Alqueva, Portugal, was constructed on the reservoir of the Alqueva Dam. It is Europe's largest floating solar installation.
- **Hapcheon Dam**: This 41-MW floating solar power plant in South Gyeongsang, South Korea, was built by floating solar developer Scotra using solar cells from South Korea-based Hanwha.

In addition to these projects, European, Asian, and North American countries have all stated aims to grow their floating wind and solar capacity as part of their wider energy transition plans. The UK has long been a global leader in fixed-bottom offshore wind production and has accelerated its plans for floating offshore wind, aiming for up to 5 GW by 2030.[9] To meet this goal, additional capacity in the Celtic Sea is being developed by the Crown Estate, which is refining potential project development areas for floating offshore wind installations.[10]

9: "Offshore Wind Net Zero Investment Roadmap," Department for Energy Security and Net Zero, March 31, 2023.
10: "Floating Offshore Wind," The Crown Estate, n.d., accessed July 6, 2023.

The US is similarly accelerating its plans for both fixed-bottom and floating offshore wind, but Europe winning most of the auctions for sites reflects the continent's more mature floating offshore wind industry.[11]

Challenges and benefits: wind

No single design is most effective, as they each have their own strengths and weaknesses, and the ideal platform design for a given installation will likely vary with site conditions and available infrastructure.

Constructing offshore wind turbines creates several additional challenges relative to onshore wind energy, including more difficult maintenance, foundation construction, and power grid connection. Floating offshore wind technologies can bring further challenges because of the increased distance from shore, deeper water, and the difficulty in designing a robust, stable floating platform. Floating platforms used in the oil & gas industry have been an excellent starting point but must be further refined to suit wind turbines. No single design is most effective, as they each have their own strengths and weaknesses, and the ideal platform design for a given installation will likely vary with site conditions and available infrastructure.[12]

Semi-submersible platforms have a high level of technological readiness and have advantages in their viability regardless of water depth and seabed conditions. They can also have more straightforward installation and maintenance because they can be constructed largely onshore and worked on in relatively standard dock conditions. The downsides of semi-submersible platforms include their larger size and their lower stability relative to spar and TLP platforms.

Spar platforms are also somewhat advanced in their technological readiness, have high stability, are not sensitive to seabed conditions, and are relatively simple structures from a manufacturing and maintenance perspective. The challenges with the spar design mostly relate to the length/height of the structure, which complicates assembly and transport and restricts spar platforms to deeper waters.

TLP designs have high stability and benefit from a small seabed footprint and a relatively small, simple structure, but they are suitable only for certain seabed conditions. In these conditions, mooring is still more complex than for other designs due to the constant tension required in each line, which can cause significant stresses in the structure and bring higher risk in case of mooring line failure.[13]

Maintenance and repair are significant challenges for offshore wind technologies, and floating platforms require their own maintenance in addition to standard turbine maintenance. Maintenance costs tend to scale with distance, making FOWT maintenance more expensive than for fixed-bottom counterparts due to the more distant installation of FOWTs. But for more infrequent, substantial repair, this is not necessarily the case. Floating platforms can be towed to locations better suited to significant repair—including nearby docks—rather than requiring in-situ repair or partial deconstruction, as for fixed-bottom designs.

11: "1st US Floating Offshore Wind Auction Nets $757M in Bids," AP News, Gillian Flaccus, December 7, 2022.
12: "Critical Review of Floating Support Structures for Offshore Wind Farm Deployment," Journal of Physics: Conference Series, Mareike Leimeister, et al., 2018.
13: Ibid.

In addition to potentially easier repair, the core benefits of FOWTs are the ability to use deeper sites than with fixed-bottom turbines, opening up substantially more sites in most regions. Importantly, this opens up not just more sites, but potentially more promising sites. Offshore wind already exceeds onshore wind in terms of capacity factor,[14, 15] and higher-quality sites—with consistent, high levels of wind—tend to be farther from shore in deeper water.[16] The Hywind Scotland project, for example, reported a capacity factor of 57.1% in the 12-month period up to March 2020—compared with the average offshore capacity factor of 43% in 2018.[17] Though the majority of FOWT designs use one turbine per platform, floating designs offer potential benefits for multi-turbine approaches, simplifying the process of aligning the turbines to maximize wind utilization.

For startups focusing on floating wind, permitting is a core challenge. Before large-scale manufacturing and revenue generation can begin, small-scale test projects and larger demonstration projects need to be built. Though the nature of permitting problems will depend strongly on location, permitting represents a potentially time-consuming process that generally cannot be expedited. FOWTs require site-specific permitting, including initial site assessment, construction and installation plans, environmental impact assessment, and power grid connection plans.

Challenges and benefits: solar

The platform designs derived from technologies in the oil & gas industry are suited to open ocean use, and floating solar tends to focus more on either inland water bodies or sheltered coastal bays. This changes the requirements for floating platforms considerably, as conditions will be more stable and moderate than those at open ocean sites. Similarly, the form factor of solar panels is of course much lower than wind turbines, reducing both the wind load—the force of wind on the structure—and the center of gravity. Both of these factors reduce concerns about stability, allowing for simpler, more lightweight platforms. In some cases, the floating structures can be constructed from recycled plastics or based on repurposed end-of-life aquaculture equipment, such as floating fish cages.

Floating solar energy projects are often focused on artificial water bodies to reduce concerns of ecosystem disruption. This reduces maintenance challenges considerably because access is not a concern. Similarly, grid connectivity is usually straightforward considering the short distances involved, and permitting is generally simpler than it is for floating wind technologies due to more limited ecosystem impacts and few issues with land ownership, aesthetics, and impacts on transport lanes.

Research from the National Renewable Energy Laboratory—a laboratory of the US Department of Energy—showed that for a US-based 10-MW_{DC} system, floating solar represents a cost premium of about 25% relative to a similar ground-based installation.

The most significant challenge for floating solar energy is that of cost, which varies with float design and location. Research from the National Renewable Energy Laboratory—a laboratory of the US Department of Energy—showed that for a US-based 10-MW_{DC} system, floating solar represents a cost premium of about 25% relative to a similar

14: Often given as a percentage, capacity factor is the actual energy output of an asset over a given time period relative to the maximum theoretical output over the same time period.
15: "Onshore vs Offshore Wind Energy: What's the Difference?" National Grid, n.d., accessed July 6, 2023.
16: "Offshore Wind Outlook 2019," IEA, November 2019.
17: "Future of Wind," IRENA, October 2019.

ground-based installation.[18] Of this premium ($1.29/W versus $1.03/W in 2020), the majority was made up of structural costs related to the floating platform, which represented more than three times the structural costs of ground-based solar. Floating solar saw minor savings in land acquisition costs, and many of the remaining costs were similar between the two technologies and are likely to remain close to parity. Structural costs can increase in areas with high potential wind and snow load, which influences the requirements of the floating platform.

Aside from reduced land costs—and preserving land for other uses—floating solar can have some additional benefits, including potentially increased solar panel efficiency due to the cooling effects of water proximity.[19] Water usage and loss are also potentially improved through floating solar installations. Solar installations depend on clean panels for maximum efficiency, and panel cleaning can have significant water requirements, which can be problematic considering that many high-irradiance areas are relatively arid. Floating solar installations can use the water body they are situated on for cleaning, which simply drains back into the water body, reducing water consumption significantly.

Further, the presence of floating solar installations can reduce water loss due to evaporation by acting as a shading mechanism and thus lowering water temperatures. For installations with 30% coverage of the water's surface, evaporative losses can be reduced by approximately 46%.[20] This shading also slows growth of phytoplankton, which can cause ecosystem damage during "bloom" events.[21]

Finally, floating solar installations are often located either in areas of high electricity consumption (on water bodies near population centers or industrial sites) or in relatively remote areas that do not have good power grid connectivity. This allows them to either maximize their output in areas of high demand or act as replacements for local power generation in more remote sites, which is often provided by high-carbon sources such as diesel generators.

Select company highlights

Wind Catching Systems

WIND CATCHING

Founded: 2017

Employees: 9

Total VC raised: $13.8 million

Last financing: $10.0 million in Series A funding

Last financing valuation: $40.0 million

Lead investor: GM Ventures

Wind Catching Systems (WCS) is a Norway-based developer of floating offshore wind technology. The most common designs for FOWT use a single floating platform per turbine and similar turbines to standard onshore and fixed-bottom offshore projects. WCS is instead developing a multi-turbine approach on a semi-submersible platform. Other multi-turbine approaches tend to use two or three large turbines per platform, but WCS' design uses an array with a high number of smaller turbines, increasing the swept area per platform. The array design is a novel approach, and in theory, it can ease maintenance challenges by situating more power generation on a single platform connected by a shared framework. Aside from simply increasing the

18: "Floating Photovoltaic System Cost Benchmark: Q1 2021 Installations on Artificial Water Bodies," National Renewable Energy Laboratory, Vignesh Ramasamy and Robert Margolis, October 2021.
19: "Study on Performance of 80 Watt Floating Photovoltaic Panel," Journal of Mechanical Engineering and Sciences, Zafri Azran Abdul Majid, et al., December 2014.
20: "Energy Production and Water Savings From Floating Solar Photovoltaics on Global Reservoirs," Nature Sustainability, Yubin Jin, et al., March 13, 2023.
21: During bloom events, the rapid growth of algae reduces water quality.

number of viable sites for the technology, combining this multi-turbine design with a floating platform has an additional benefit of allowing the platform to more easily orient itself toward the wind. Single-turbine designs typically do this by rotating the turbine/nacelle on the support column.

WCS has raised three rounds of VC funding. The most recent was in June 2022 for a $10.0 million Series A led by GM Ventures to further develop WCS' floating wind technology. WCS also received grant funding in 2022 and 2023 from the Norwegian Ministry of Climate and Environment for design, construction, and testing of a pilot project for its technology.

EOLINK

Founded: 2016

Employees: 25

Total VC raised: $13.1 million

Last financing: $10.7 million in late-stage VC funding

Last financing valuation: $25.5 million

Lead investor: Acciona Energía Internacional

Eolink

Based in France, Eolink develops floating wind technology based on a square semi-submersible platform with four floats. The choice of semi-submersible platform simplifies construction and installation, and the four-float platform reflects the design of the turbine used by Eolink. Unlike conventional single-turbine designs, which use a single mast with the turbine and nacelle able to rotate on top to face the optimal wind direction, Eolink's design uses four masts that connect in a pyramid shape, with the center of the turbine at the apex. This design would be far less viable for fixed installations due to the challenge of reorienting direction but is well suited to floating applications and can distribute stresses more effectively, reducing the strength required—and thus the materials needed.

Eolink received funding and support from the incubator Emergys Bretagne in 2016 and has since raised four rounds of VC funding, the largest being $10.7 million in late-stage VC funding from Acciona Energía Internacional and other investors in 2022. The company is currently developing precommercial projects ahead of its first small-scale commercial project, which is slated to begin in 2026.

inseanergy
Green leadership

Founded: 2020

Employees: 10

Total VC raised: N/A

Last financing: Undisclosed early-stage VC funding

Last financing valuation: N/A

Lead investor: Oxidane Venture

Inseanergy

Inseanergy develops floating solar technology primarily to support the aquaculture industry. Based in Norway, Inseanergy is currently focused on Norwegian markets but aims to expand to other geographies later. Norway's aquaculture industry involves locations all along Norway's coast, including many somewhat remote regions that are not well connected to electrical power grids and thus rely on local diesel generators. Inseanergy develops solar technology based on floating platforms made from repurposed end-of-life floating fish cages—the cages below the waterline are removed, simplifying the structure and allowing added weight above the waterline in the form of solar panels. These platforms are widely available in regions with substantial aquaculture industries and are mostly standardized, allowing common designs to be used. The technology is currently aimed at supplementing diesel generators rather than replacing them entirely, though future plans include the addition of hydrogen generation to generate clean fuel on-site. The company's technology can also be paired with battery energy storage to further increase its use outside of peak sunlight hours.

The company completed a pilot project in collaboration with Norwegian salmon farming company Hofseth and is currently developing commercial offerings.

SOLARDUCK

Founded: 2018

Employees: 14

Total VC raised: $4.4 million

Last financing: $4.4 million in early-stage VC funding

Last financing valuation: N/A

Lead investor: Link Venture Capital

SolarDuck

Headquartered in the Netherlands, SolarDuck develops floating solar technology intended for offshore applications. This contrasts with most floating solar startups, which focus on artificial water bodies or coastal or inland aquaculture. SolarDuck's technology uses triangular floating platforms that are connected to form a large floating structure using a semi-submersible design to cope with the more significant wave and wind conditions encountered offshore. The connected nature of the system has benefits around shared electricity transmission infrastructure and also adds structural support while providing a level of flexibility to handle larger waves. The floating platforms and solar panels are designed to minimize maintenance, using passive approaches through material choice and panel angle, and the platforms also have walkways throughout to simplify any active maintenance that must occur.

SolarDuck has built pilot projects at smaller scales and is currently developing a pilot project based on six interconnected platforms, with a peak output of 500 kW. This project will test the technology at scale in the North Sea to assess performance in real-world conditions.