Floating Solar in Asia

FLOATING SOLAR CONFERENCE
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SOLARPLAZA

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Acknowledgments

We would like to extend a special thanks to **Celine Paton** from the Solar Energy Research Institute of Singapore and **Tianyang Qin** from Sungrow for contributing their invaluable expertise to the drafting of this white paper.

SERIS Solar Energy Research Institute of Singapore

SERIS has been leading Floating PV research in Singapore and worldwide. SERIS has managed the design and construction, and is now operating the world's largest testbed for Floating PV at Tengeh Reservoir since 2016.

SUNGROW Clean power for all

Sungrow has been dedicated to the renewable energy industry for more than 23 years. Facing the global demands of floating solar plants, Sungrow has established a specialized research and manufacturing base for floating solar plants. The total installed capacity of Sungrow floating solutions has exceeded 1 GW.

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Nomenclature & Acronyms

CAPEX	Capital expenditures
FPV	Floating Photovoltaic
GWp	Gigawatt peak
LCOE	Levelized cost of electricity
MWp	Megawatt peak
O&M	Operation and Maintenance
OPEX	Operating expenditures
SERIS	Solar Energy Research Institute of Singapore

Introduction

Since the development of the first floating photovoltaic (FPV) power generation system in Japan in 2007, the application of such systems has gradually gained popularity in many countries around the world including China, South Korea, Taiwan, France, the Netherlands, Vietnam and the US. The last three years were particularly important in terms of global FPV capacity gain. From 2017 onwards, the annual capacity additions have become significantly higher due to the increasing number of large-scale projects primarily in China. Although today operational FPV plants can be found on every habitable continent on earth, Asia's dominance in the number of projects and cumulative installed capacity is indisputable.

As highlighted in Solarplaza's analysis of the "Top 200 Operational Floating Solar Projects", Asia is home to more than 94% of the total capacity of the 200 largest FPV projects on that list. The picture is very similar when looking at the spatial distribution of global installations. The 2019 data from the Solar Energy Research Institute of Singapore (SERIS) speaks to that, as it shows that 95% of the 1.8 GWp global FPV capacity was located in Asia.

For the near future, Asia is expected to continue to be the hotbed for the development of FPV technology. Next to the dominance of China and Japan, more large-scale FPV projects are being developed in emerging markets like Singapore, Thailand, Taiwan, South Korea, Indonesia, Malaysia, Vietnam, Laos and India. To get a better idea of how the Asian FPV market will develop in the upcoming years, Solarplaza reached out to Celine Paton, Senior Financial Analyst at SERIS and Tianyang Qin, Overseas Business Development Manager at Sungrow for their take on the future of FPV. With the help of Paton and Qin, this paper aims to shed light on the most recent trends in the Asian FPV markets, the benefits and challenges of developing FPV projects in different environments, and their relative costs.

Development of the Asian FPV market

As mentioned in the introduction, it was in Japan where solar PV panels were first installed floating on the surface of a lake in 2007. Since then, the deployment of FPV has grown significantly around the world, with the majority of projects being concentrated in Asia. Similar to the deployment of other new technologies, the early FPV projects were small-scale installations. Since 2013, FPV technology has been advancing rapidly though, which has led to a surge in commercial projects, primarily in Japan and South Korea.

However, it was China's entrance to the FPV market that helped the technology take off. What was at that time just a niche market became one of the fastest growing new PV deployment options. While 2013 marks the year in which South Korea built the world's first FPV project with a capacity of 1 MWp, China's involvement paved the way for the realization of considerably larger FPV projects

In 2016, China became home of the largest FPV project thanks to its newly commissioned 20 MWp plant located in a coal mining subsidence area. Later in 2018, China made headlines again by bringing online a 150 MWp project, the largest FPV project to date. Although larger projects have not been commissioned in the last two years, there have been several large-scale FPV projects completed. The table below highlights the world's ten largest FPV projects, which clearly shows China's dominance in the global FPV market *(Table 1)*.

It is interesting to note that all of the listed projects are located in Asia, and nine of them within the borders of China. Also, the total capacity of the ten projects - all of which were built between 2017 and 2019 - accounted for about 50% of the global FPV capacity at the end of 2019.

Table 1: Top 10 operational FPV projects

Name of plant/ region	Scale (MWp)	Country	Operational Year	Floating System Provider
Anhui province	150.00	China	2018	Mixed Chinese
Guqiao Huainan/ China coal subsidence	150.00	China	2019	Sungrow
Yingshang coal mining subsidence area	130.00	China	2018	Mixed Chinese
Xinji Huanian/ China coal subsidence	102.00	China	2017	Sungrow
Weishan Jining/ China large-scale waters	100.00	China	2018	Sungrow
Hunan River	100.00	China	2019	Sungrow
Anhui Cecep	70.00	China	2019	Ciel & Terre
Huancheng Jining / China coal subsidence	50.00	China	2018	Sungrow
Da Mi Hydropower Reservoir	47.50	Vietnam	2019	Narime-Qihua
Coal mining subsidence area of Huainan City	40.00	China	2017	Sungrow

However, while China has been gathering a lot of buzz during the last few years, other Asian countries have started to also crank up their development of FPVs. According to Celine Paton, these countries include Singapore, Thailand, Taiwan, South Korea, Laos, Indonesia, Malaysia, Vietnam and India.

Thailand announced that it has 2.7 GWp of FPV projects under development in combination with 9 hydropower plants. Taiwan is also boasting impressive projects, including a new record-breaking 181 MWp project set to come online later this year. South Korea has more than 2 GWp of FPV in the pipeline, all of which are located on the coast of the Yellow Sea. Similarly, Laos announced that it plans to develop 1.2 GWp of FPV plants on a single dam, while Taiwan and Vietnam, both known for their utility-scale sector, have made a big step for FPV by including the technology in their feed-in tariff schemes. Last but not least, India has also been on the rise lately with the announcements of multiple FPV tenders, many of them in very large scale (>100 MWp). As Paton explained, the other main trend in the Asian FPV market is that the

"Development Banks, such as the World Bank and the Asian Development Bank, and their private sector arms are increasingly engaging with governments to advise them on site selection and regulatory best practices such as power purchase agreements and public-private partnerships."

As the list of largest projects indicate, most of the utility-scale projects have been developed on industrial basins such as flooded coal mining subsidence areas. An interesting trend with enormous development potential is the use of hydropower reservoirs for the deployment of Floating PV. The Vietnamese hydro-FPV hybrid plant in the top ten largest projects is one such example. Together with other announced large-scale projects on hydropower dams (e.g. in Thailand), this indicates a maturing of FPV technology that can successfully withstand the significant water-level oscillations. An even more promising sign is the emergence of FPV projects in (semi-)marine environments, which suggests that some of the FPV equipment can already offer long-term resistance against the harsh environmental conditions that are present in near-shore locations. Once these new technologies will prove to be reliable in the long run and at a reasonable cost, FPV technology could unlock an immense amount of additional area for development. To see what the challenges and opportunities of FPV applications are in the above-mentioned water bodies, the following section will discuss the specific requirements, and possible benefits of FPV systems at freshwater basins, hydropower plants and marine environments.

The deployment of FPV technologies in different environments

Freshwater basins

As the very first FPV systems were developed on industrial and agricultural water bodies, freshwater basins can be considered the cradle of the technology. The layout of the systems in such basins show similarities with their land-based counterparts. For example, it is possible to use the same PV modules, inverters, transformers and cabling for both the land-based and FPV systems as long as the water impermeability of the components is assured.

On the other hand, the most obvious difference between the layout of land-based PV and FPV systems is that the PV modules of FPV systems are mounted on floating structures. Depending on the size and location of the project, the inverters can be placed on land or they can be floating on special platforms. The inverter of a small FPV project close to shore can be placed on land, which can decrease the capital expenses (CAPEX) of the project. However, projects that are larger or far from the shore benefit from floating inverters to reduce DC cabling costs and losses. The other main difference is that FPV systems have to utilize mooring and anchoring systems in order to fix the floats, and thus, keep the whole system in their correct place.

The appropriate mooring and anchoring of FPV systems is a critical step, as they have to do their job regardless of the water level oscillations of the basin or the high wind speeds even under extreme weather conditions, such as during tropical cyclones. This is an especially important factor to consider in the western Pacific regions, where the frequency of tropical cyclones (called typhoons in the region) is the highest on Earth.

Once these challenges have been overcome, the benefits of FPV systems on freshwater basins are manifold. On top of the often-cited benefits of every FPV system over land-based PV systems, such as the increase in energy yield due to the cooling effect from the water (which is climate dependent), decrease in shading and in certain cases soiling, as well as easier site preparation and installation, the development and operation of FPV projects on freshwater basins could largely benefit the communities located in the vicinity of the projects as well. For example, the inhabitants of the province of Anhui in China are now making their money out of FPV project installations and their operation and maintenance on flooded coal mines. Just a few years back, these people were working as coal miners, from which profession they generated lower income and were also subject to high risks of health hazards. So by turning the flooded coal mines of the area into lucrative solar business opportunities, communities of the area saw multiple benefits on both the environmental and social sides.

In general, the water level oscillations, water depth, soil conditions, wind speed and the size of the waves are all factors that determine how costly and challenging the installation and operation of an FPV plant will be.

Hydropower & FPV hybrid

From a systemic point of view, there is currently hardly any better renewable energy generation option than the coupling of FPV with hydropower. One advantage is that the grid connection of the FPV plant in many cases can be realized through the existing infrastructure of the hydropower plant, which significantly reduces the CAPEX of the project. In addition, the adjustability of the hydropower plants (depending on the turbine type) means that the variability of the solar power generation can, at least partly, be compensated. On a diurnal cycle, the water resources of the hydropower plant can be saved during the day and then released at night (Figure 1).

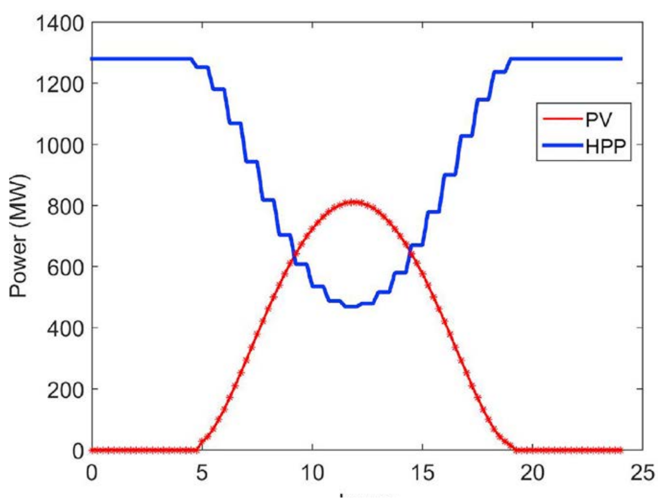


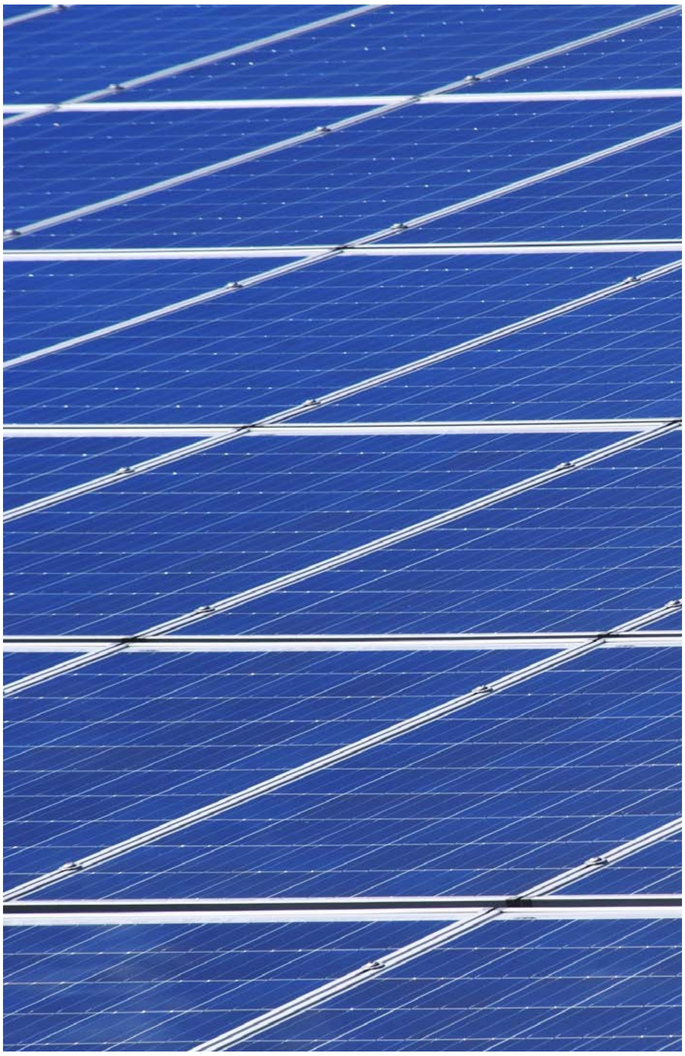
Figure 1: *Power output of hydropower and solar PV during a sunny summer day for the Longyangxia plant (Cazzaniga et al., 2019)*

Furthermore, the water resources could also be saved during certain times of the year. According to Sungrow's Qin,

"the application of a floating power systems has the potential to reduce the water evaporation. The reduction rate will depend on the water surface coverage ratio and the season but according to our simulations, the water evaporation could be reduced by almost 30% with full surface coverage during dry and hot seasons."

Finally, in the temperate and monsoon regions of Asia, where the precipitation is highly seasonal, the hybridization of hydropower with FPV has the potential to compensate each other on a seasonal basis. During the dry season, when the hydropower plant has lower electricity output due to the scarcity of water resources, the conditions are optimal for solar energy generation. During the wet season, the exact opposite happens, and therefore, the hybrid solution reduces the yearly electricity generation fluctuations of the two technologies.

When Qin was asked about the challenges of FPV installations on hydropower dams, she highlighted the large water level variations and the need for deep water anchoring. However, the use of underwater robots and positioning devices can assist deep water construction, and as such, the quality of anchoring can be assured.



Marine installations

The application of FPV systems in near-shore and off-shore environments is a relatively new concept. Although it could offer an ocean (literally) of potential for FPV, they also present some additional challenges. The extreme environmental conditions (e.g. combined wind and waves, tides) and the marine atmosphere (e.g. salt mist, biofouling) that are present in such sea spaces were underlined as the main difficulties for the commercialization of FPV on seawater by both Paton and Qin. In marine environments, especially off-shore, the mooring and anchoring of floats is a huge challenge, where next to the bigger and often choppier waves, more powerful winds and significantly larger depths, the tidal movements and currents of water bodies also need to be considered. In addition, the salinity of water and the surrounding air also pose some challenges.

To overcome these issues, there might be a need for re-designing the floating structures and mooring and anchoring systems so that they can withstand the continuous occurrence of extreme conditions on the long run. As Paton explained, the knowledge of marine and off-shore industries could be utilized here.

"There is still a need to do more research, pilot studies and demonstration in marine conditions at a smaller scale, before we can have larger commercially viable FPV systems out at sea. Some solutions of related industries such as off-shore and marine could in principle be applied, but the problem is the cost of these technologies. In the extremely competitive solar energy industry, where the margins are rather thin, a cost-effective design is a prerequisite."

On the other hand, there are already several companies that are researching the viability of off-shore FPV, and as a result, we can already see the emergence of off-shore pilot projects. For example, the world's first off-shore FPV system was successfully installed in the Dutch North Sea in 2019.

Alternatively, the application of FPV near to the shore is not as challenging as in the open waters, and therefore, we can already see the emergence of bigger projects primarily in lagoons, bays and atolls, where the water is relatively shallow and the waves are smaller. Some of the countries that are operating or developing near-shore FPV plants are the Maldives, Norway, Singapore, Taiwan, South Korea and the Seychelles.

In general, however, there are still a lot of uncertainties regarding the costs and long-term durability of equipment in marine environments.

Middle-East near-shore 80kWp FPV Project (Courtesy of Sungrow Floating)

Costs of FPV

The total capital expenditures of an FPV system will depend on many variables, and therefore, it is very difficult to generalize. First of all, the CAPEX of a project will depend largely on the complexity of a specific project. As already mentioned, the water depths, water level variation, bathymetry, soil conditions at the bottom of the reservoirs, wind speed and possibly waves (for larger reservoirs) are some of the most important factors to be considered, as are tides, waves and the corrosive environment in marine spaces. Second, the CAPEX of an FPV project is also country-specific. For example, the reported FPV system costs are significantly higher in Japan than in China and India, a trend that can also be observed for other types of solar system installations.

If we make a comparison between the capital costs of FPV systems and land-based systems, the CAPEX of an FPV system used to be higher. According to a report written by SERIS and the World Bank Group, "Where Sun Meets Water", the total CAPEX for FPV systems in 2018 ranged between $0.8 and $1.2 per Wp. However, that has changed since and in some of the most competitive markets such as India and Thailand, as Paton added, we can now see projects rolling out at much more aggressive turnkey prices of about $0.5 per W.

In China, one of Sungrow's large-scale projects was also completed at a capital cost of around $0.55 per Wp in 2019. The breakdown of the system costs reveals that the costs of floats and PV panels accounted for about three-quarters of the total expenditures *(Figure 2)*.

According to Qin, the capital costs of FPV systems are expected to decrease over time mainly due to the projected cost reductions of PV modules and floats. She also added that the cost reduction of floats will be achieved by the optimization of manufacturing technique and floating design as well as the economies of scale.

Generally speaking, the operation and maintenance (O&M) activities of an FPV plant is more complex than that of the land-based systems. Although the soiling of the panels is generally less of an issue (but again this is site-specific), some of the maintenance activities require specialized personnel. For example, the inspection and maintenance of mooring and

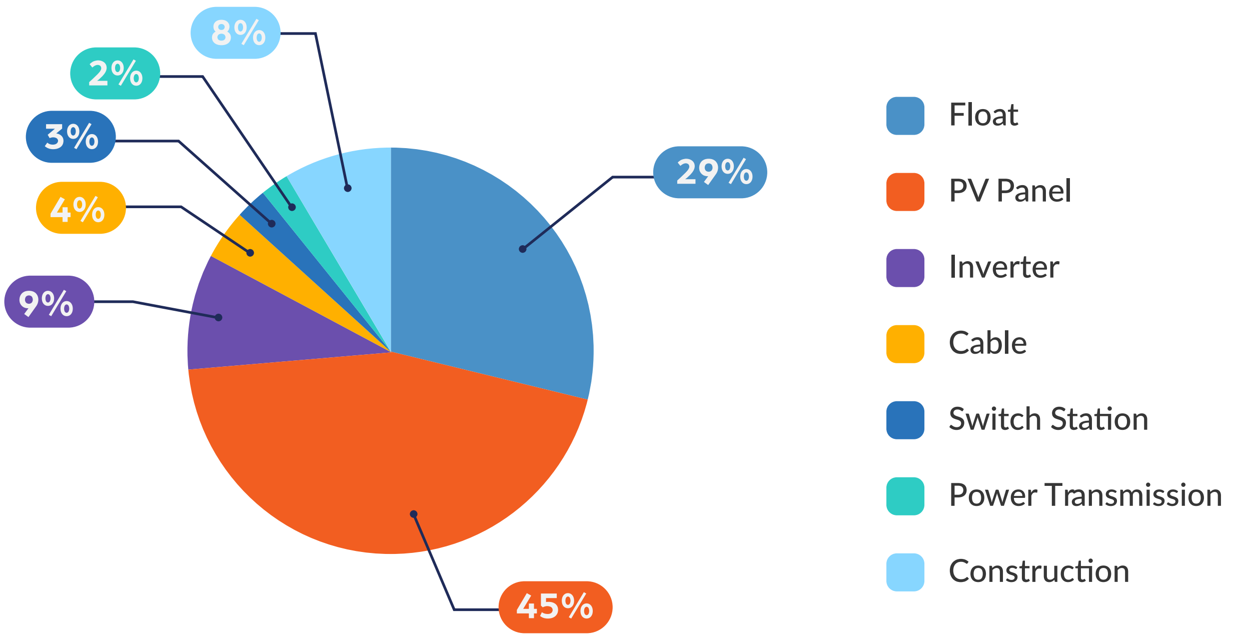


Figure 2: *Breakdown of a large-scale FPV system cost in China (Sungrow)*

anchoring systems are often done by divers. Furthermore, for most of the FPV systems, a boat is required to access the plant. However, these are not the only factors that affect the O&M cost of FPV systems. Just as the CAPEX, the operating expenses (OPEX) of projects will also be affected by the wind speed, the size of waves, the water level oscillations and the salinity of the water (where applicable). In addition, in some regions, the accumulation of bird droppings on the systems was also identified as an O&M issue that necessitates frequent cleaning.

All things considered, we can see that the CAPEX and OPEX of an FPV system will vary significantly depending on the environmental conditions of the project site, but most of the industry representatives believe that the more capital intensive investment of FPV projects can be balanced out during the long-term operation of the plants, thereby, the levelized cost of electricity (LCOE) of the project could generate similar values than a comparable project on land.

Closing words

Although still in its infancy, the growing number of large-scale FPV projects are signaling that the technology is already commercially viable in Asia and in other parts of the world, too. This is good news considering that the cost of the technology is expected to see further decrease thanks to its increasing market penetration, and the optimization of equipment and FPV system design.

However, we saw that the CAPEX and OPEX of FPV plants are highly site- and country-specific and that some of the potential environments for FPV deployment are still posing technological, operational and financial challenges to the industry. We can also see that there are relatively high levels of uncertainties around the long-term durability of the systems as well as their impact on the ecosystem and the quality of the water.

The limited amount of long-term data suggests that we will not be able to immediately answer all of the questions regarding FPV, but the ramping up of floating solar installations around the world will not only increase data availability, but it will also help find solutions to some of the above-mentioned issues, will push the technology down the learning curve, and most importantly, it will strengthen the solar industry as a whole by unlocking an immense amount of additional potential for solar energy generation.

To learn more about the advantages, challenges, development and potential of FPV, and meet the leading players active in this space, join the International Floating Solar Conference 2020, taking place in the Taets Art and Event Park in Amsterdam on November 4.

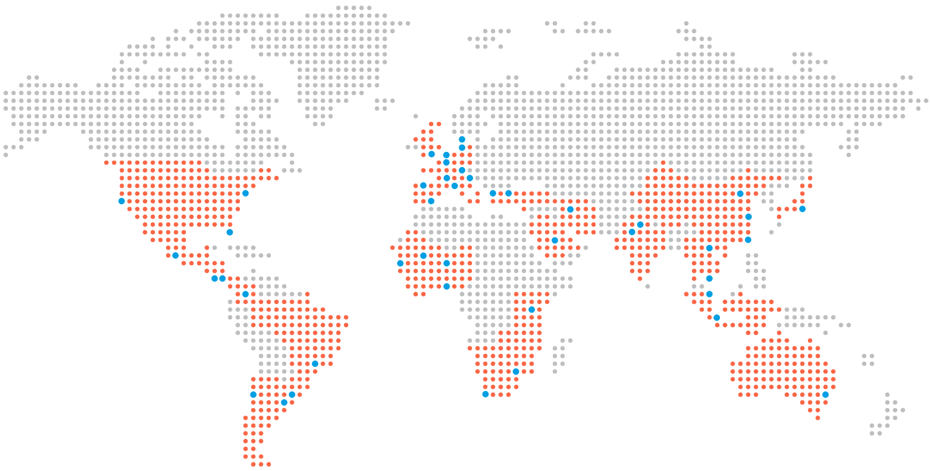
Sources

Cazzaniga, R., Rosa-Clot, M., Rosa-Clot, P., & Tina, G. M. (2019) ***Integration of PV floating with hydroelectric power plants***. Heliyon, 5 (6), e01918.

Oceans of Energy (2019) ***A world's first: offshore floating solar farm installed at the Dutch North Sea. Retrieved from:***
https://oceansofenergy.blue/2019/12/11/a-worlds-first-offshore-floating-solar-farm-installed-at-the-dutch-north-sea/

Santiago, C (2020) ***Floating solar energy projects gain traction in Asia. The Asset.***
Retrieved from:
https://www.theasset.com/article-esg/40411/floating-solar-energy-projects-gain-traction-in-asia

World Bank Group, ESMAP and SERIS (2019) ***Where Sun Meets Water: Floating Solar Market Report***. Washington, DC: World Bank. Retrieved from:
https://openknowledge.worldbank.org/handle/10986/31880



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