Keeping it clean

Cleaning | As detailed in the previous article, research into the soiling of solar modules is shedding new light on the problem, its impacts and the best solutions. Sara Verbruggen looks at some of the available latest technologies, the economics behind them and how they are being deployed in the field

Credit: Ecoppia

What's the best approach when it comes to reducing panel soiling in dry, dusty environments? While cleaning panels using water is the most effective way of eliminating soiling, in a growing number of markets a dry cleaning approach is more suitable, with a market that is evolving to sustain various solutions spanning low-tech and relatively low investment tractor-mounted brushes to a fully automated service, administered by sophisticated technologies.

Market drivers and cleaning approaches

As the cost of solar technology has fallen, this has helped unlock demand in emerging markets. In many instances such markets tend to be in dry, subtropical regions, such as the Middle East and North Africa, India, and Latin and Central America.

Drivers for dry cleaning of PV modules can include regulations prohibiting or limiting water consumption, water scarcity, high water rates or costs associated with water infrastructure, such as pumps and reservoirs, if sites are remote from water sources. Where there is access to water for cleaning, low-tech manual methods can be used. But these can impact operational expenditure, depending on local labour costs and other factors. And as detailed in the previous article, soiling is a higly location-specific phenomenon, meaning the final choice of cleaning method and strategy will be informed by the specifics of individual projects.

From a solar asset owner or operator's perspective, cleaning solutions are broadly categorised in terms of capital expenditure (capex) versus operational expenditure (opex), according to Dr Marc Korevaar a scientist in the research department at solar instrument producer Kipp & Zonen.

"Manual cleaning has the lowest investment, or capex, cost but highest opex, due to the cost of labour. Truck-based – semi-automated – cleaning has an intermediate investment cost and intermediate labour opex and tends to be used in places such as the US, parts of Europe, as well as parts of the Middle East," he says.

New cleaning technologies are helping developers improve project yield and cut O&M costs

Brush cleaning involves a driver manoeuvring a truck or tractor, mounted with a crane jib and brush, to move along a row and clean each panel.

"Fully automated, or robotics-based, cleaning, has the highest investment cost and the lowest labour opex and tends to be used in places with high soiling where water is also scarce and so is expensive as well as where labour costs being higher," Korevaar says.

"One of the drivers for fully automated cleaning, which has emerged in more recent years, that we are seeing, is the general trend towards larger solar plants. Labour costs, as part of operations and

maintenance (O&M) opex, can be significant to keep modules clean at sites that are hundreds of megawatts in size."

Anat Cohen Segev, vice president of marketing at cleaning robot manufacturer, Ecoppia, says vice says automated robotics cleaning technology provides benefits to solar asset owners in two ways: "Cleaning increases energy output of solar panels, thus higher revenues from increased output. This can be beneficial where installations are getting subsidy payments, as additional MWh generated results in subsidy payment on top of the electricity price.

"O&M opex savings are also realised through elimination of labour costs and water and associated infrastructure costs of getting water to site, storing it and because there is also less vegetation to maintain as well."

Korevaar thinks that the growing awareness among operators of the amount of losses due to soiling that can occur is leading to more interest to measure and understand causes of soiling and levels of soiling and using this data to decide on the most suitable dry-cleaning approach.

The same Fraunhofer CSP study cited in the previous article, estimating that the global solar industry loses €3-5 billion annually from soiling, also predicts that by 2023 that loss could increase to around €4-7 billion. This is partly down to more solar capacity being installed in high insolation regions, also with high levels of soiling, such as China and India, where lower prices paid for electricity can act as a disincentive to clean modules.

Quantifying soiling

Kipp & Zonen's DustIQ system for measuring and monitoring soiling from dust is used by around 60 solar asset owners and developers globally, according to Korevaar.

"Understanding potential losses from soiling has helped stimulate interest in how soiling levels can be mitigated during solar plant operational phases," he says.

Over large solar park sites, DustIQ can be used to measure differing soiling levels across the entire site. "For example, proximity to roads, or certain wind conditions, can result in higher soiling in localised areas.

"We are generally seeing a demand for measuring soiling in all regions that are dry and therefore have a lot of natural soiling. Furthermore, regions where there is manmade soiling, due to factories or mining activity, for example, creates additional need for using tools to accurately quantify soiling levels."

DustIQ customers are primarily engineering, procurement and construction (EPC) companies that are building new plants, as well as O&M providers retrofitting soiling sensors at PV plants. The measuring system is also applicable in solar plant development, during site selection.

"For example, where a developer may have two or three potential sites for development, the sensors and measuring instruments can be installed around the sites to collect data on the different soiling levels at each site, which can then feed into criteria when deciding which site to develop," Korevaar explains.

The measuring system can also be deployed to inform solar plant design to mitigate or reduce the level of soiling, by planting vegetation as a screen from dust and particulates around the edge of the solar park, or by installing panels at higher levels, where soiling is reduced.

DustIQ can also be deployed in operational solar facilities. Operators can use it to measure dust and particulates to assess soiling levels and then use the information to inform module cleaning schedules and which approach is the most relevant. "They can decide if a high capex but low opex or low capex, high opex method is best," says Korevaar.

Approaches and cleaning techniques are influenced by several factors. For example, in very dry and arid regions, such as south-west USA where condensation (dew) levels are low, panel soiling is less comparable with parts of the Middle East, where dew or condensation on the panels attracts dust and dirt to adhere to the panels and for soiling to build up, requiring more cleaning.

Other factors include cost of water as well as associated infrastructure. "In south-west USA, water costs are cheaper compared with other arid, dry regions, such as Saudi Arabia, where soiling levels are not only high, but water costs are high too, making dry-cleaning robots more feasible," Korevaar says.

Robotics versus brush cleaning

Norwegian developer Scatec Solar's portfolio encompasses PV plants in more than 10 countries, in a range of locations. In parts of Europe where there is rainfall in sufficient quantity, most soiling is washed away, so minimal cleaning is needed. But the company also owns plants in Egypt and Jordan where there is very low rainfall throughout the year, allowing dust and other particles to build up significantly and requiring continuous cleaning.

Scatec Solar senior vice president for O&M, Pål Strøm, says: "There is no one-size cleaning solution. Selecting a solution comes down to a capex and opex calculation, which takes into account the detailed characteristics of the site and performance of the cleaning solution."

Before a project is constructed Scatec Solar carries out a detailed site study, to model soiling levels, based on measurements of rainfall and humidity levels, wind speeds and direction, dust and soil particle analysis and vegetation type.

Then, the most suitable cleaning approached is assessed. Several factors are evaluated, for example cost of labour, cost of water, fuel cost, as well as cost of water infrastructure, according to Strøm.

"Cleaning solutions fall into three main categories. Manual, which is where people are employed to clean panels. Trucks or tractors mounted with brushes, which can be used for wet or dry cleaning. Then there is fully automated cleaning using robotics solutions," he explains.

In low soiling environments, where manual cleaning is a cost-effective solution, Scatec Solar outsources to a subcontractor. "Where we have PV plants in drier and dustier regions, historically the company's main approach has been

Credit: Scatec Solar

Semi-automated, truck-based cleaning has proved to be a low-risk, cost-effective solution, but is likely to be superseded by robotic technologies

to use brush-mounted trucks as it is a low risk and proven approach, as well as being cost-effective," he adds.

This method has been deployed at the company's plants in Brazil and Egypt, where soiling rates are high in both locations. "Scatec Solar will invest in the tractors and equipment and have operators to carry out the cleaning, which is more of an insourced approach."

Scatec Solar is planning to deploy its first robotics solution at a 117MW plant currently under construction in Argentina, expected to be completed in first quarter 2020.

"The key driver for going with a fully automated robotics solution is to increase yield. Even though the opex is low, robots require significant capital investment in this equipment, so in order to rationalise that high capex, the solar farm needs to be in an environment with very high soiling levels, where continuous cleaning is required," Strøm says.

There are different investment and ownership models that are offered by the providers of robotic cleaning systems. In some cases, maintenance can be outsourced to the providers of these systems, according to Strøm.

"Once we have gained more operational experience with robotics solutions, we will reassess our strategy with the view to introducing automated cleaning, where profitable, at our existing plants in markets, such as Egypt. For new plants, robotics is already part of the operational concept where profitable.

"It is important to mention here that where PV plants are being operated in emerging economies, the trend towards automated cleaning poses asset owners and operators with a dilemma, which is that it takes away jobs," Strøm adds.

Solar technology does not require much manual maintenance activity, compared with other technologies, such as wind, for example. Manual or even truck-based cleaning employs people in local economies.

"It is not such an issue for new projects in development where the market is highly competitive and the economics in specific locations could favour automated cleaning over other more conventional approaches to optimise yields and efficiencies, but it is why we are carefully assessing how we roll out automated cleaning, using robotics solutions, at some existing solar locations with high levels of soiling, such as the Middle East and North Africa."

Strøm says other approaches to minimising soiling levels have been considered, for example, stowing panels at a steeper angle/gradient at night. "But you also have to consider the wind factor also," he adds.

Demand for robotic cleaning

Ecoppia has developed a fully automated robotic panel cleaning platform, which eliminates labour costs associated with panel cleaning, as well as water and related logistics and infrastructure costs.

The company's technology is the only IFC/World Bank-certified robotic cleaning system. If a developer is seeking IFC financing for its solar plant, then Ecoppia is the only robotic panel cleaning system it can use.

Developer clients include SoftBank, Fortum, EDF, Engie, Actis and Renew Power. The technology has also been tested and endorsed by solar module manufacturers, including First Solar.

Return clients include Japan's SoftBank, where Ecoppia recently provided its cleaning robots for a 580MW plant in India.

Over 2GW-worth of ground-mounted solar modules are cleaned by Ecoppia's robots, with a significant portion of this capacity installed in India. Other markets include the Middle East, south-west USA and recent projects in Chile. The company also has a 5GW global pipeline of secured projects at various stages of development, in markets in Latin and Central America, the USA, the Middle East and India.

"Demand is very high in Latin and Central America, as well as in Spain, in Europe. We're also seeing interest from Australia, which we are targeting," says Cohen Segev.

Initially, Ecoppia targeted markets where water scarcity has been an issue or where logistics and cost of getting water to sites for cleaning is challenging, according to Cohen Segev.

"Today, we see that there are other key drivers for using robotics cleaning. In dry, dusty regions with high levels of soiling, solar asset owners are looking to eliminate labour costs to reduce overall O&M costs, for example. Robotic cleaning can also recover sites instantly post dust storms, as well as provide operators with clear visibility for cleaning efficiency and cost through the project lifetime.

"As PV plant projects increase in size manual cleaning is simply not sustainable, and not feasible logistics wise."

Ecoppia provides two robotic systems.

Credit: Ecoppia

Ecoppia's T4 model is aimed at single-axis tracker installations

The E4 robot is for fixed tilt and seasonal tilt solar installations able to clean long arrays during each nighttime operation. The T4 robot for single-axis tracker installations was launched earlier in 2019. According to Ecoppia, global demand for the T4 is in excess of 1GW.

Cohen Segev says: "Clients want an end-to-end solution for their entire portfolio. They often have projects in different geographies that span use of fixed-tilt and single-axis tracker. The T4 allows us to fully support our clients with a dedicated solution for each technology, to maximise cost effectiveness. In addition, it allows us to expend to additional markets."

Though Ecoppia supplies retrofit projects, the company is becoming increasingly involved in greenfield projects from the design phase, according to Cohen Segev.

"As panel cleaning is a large part of O&M costs, project developers will factor in robotic cleaning as criteria for designing arrays and layouts in order to minimise robots required. In the case of some clients, we're involved at the tendering stage.

"Where our input is considered for the design phase of a PV plant, it can result in designing arrays to keep number of robots to a minimum, to keep costs down. In some cases one robot would be needed for 3-4MW in a large solar farm."

The cloud-based platform also developed by Ecoppia allows robots to be remotely managed at any global location. The company is able to integrate additional tools into the software to improve performance, such as weather forecasts.

"Generally speaking the artificial intelligence technology we have developed is able to exploit links between seasonality, geography and weather to optimise cleaning," she says.

Future developments and technologies

In the nearer term, robotics cleaning systems, such as Ecoppia's, will open up more demand as costs for the robots

come down and the technology becomes smarter to deploy.

"Today we are seeing automated cleaning solutions that are deploying 'big data' and analytics, feeding in weather forecasts to optimise cleaning and tell the robots to stow themselves in strong winds, for example. But as robotic cleaning becomes more widespread, these machines could also be deployed in future to detect issues with panels, such as microcracks, as they pass over them, providing other types of maintenance functionality at the individual panel level on a near-daily basis," Strøm envisages.

Advances in unmanned aerial vehicles (UAVs), combined with software engineering and artificial intelligence are enabling automated cleaning of structures by drones. Aerial Power, headquartered in the UK, is one such start-up. The company's proprietary technology uses the drone's airflow to generate thrust but also blow sand and dust away from the panel surface. The drone uses sensors to detect the panel's or row's geometrical characteristics and aligns the UAV for cleaning.

One of the benefits of this approach means no loads are applied that creates pressure on the panel surface.

Prototypes have been tested in various locations since 2014, including panels in Chile's Atacama desert and at a site in Rajasthan in India.

Since patenting its concept Aerial Power has offered to license it to various utilities and other owners of solar assets in regions of the world with dry, dusty climates where wet cleaning is not feasible.

Company founder Ridha Azaiz says: "Generally these companies are interested, as they believe it can overcome shortfalls of other automated solar clean systems that they have tried using." But he thinks it will be another two years before his company's technology is commercially ready for solar panel cleaning.

"We've been using feedback to further refine the system with the view to developing a second-generation version and we are seeking solar supply chain partners and investors to work with in order to commercialise the technology.

An alternative anti-soiling approach which is still largely in development is the use of electrostatic fields for repelling the soiling from PV modules. Transparent electrodynamic screens or dust shields repel dust particles by creating a dynamic field over a surface. However, while lab demonstrations have proved successful, transferring the technology to the field has proved challenging.

Setting the standards

As capital costs for solar have come down, operational expenditure has increased as a proportion of solar's overall levelised cost of energy. As a result, the industry is focusing more on approaches and technologies that optimise operations – maximising output but also minimising O&M costs.

"In this regard, the need for independent standards for verifying the automated cleaning solutions available will become more important," says Scatec Solar senior vice president for O&M Pål Strøm.

Efforts are underway to bring a greater level of certainty to commercial decisions on the best technologies and approaches to cleaning. Among these, testing and certification house PI Berlin has been working on a standardised testing procedure for PV module cleaning products, to enable owners of utility-scale and multi-MW PV plants and installations compare different cleaning systems.

"We want to have a baseline which the PV plant operator, or procurer of the cleaning system, can use as a benchmark to decide which solution to invest in or purchase. It also allows the provider of a cleaning system or product to see how the cleaning method could impact the module glass," says PI Berlin marketing manager Benjamin Lippke.

PI Berlin's customers are typically the owners of large PV power plants and the manufacturers of cleaning systems. "A classic example is: the operator of the PV plant wants to acquire a cleaning system and needs to evaluate it. Approval is required from the module producer that the cleaning system doesn't damage the modules and therefore void the warranty."

PI Berlin's approach is to look at the real-life conditions at the location of the plant in question. "That means identifying to type of soiling and the properties of the soiling," Lippke says. "We work together with a sand supplier which provides us with test sand from the region in question."

The testing sequence itself contains several elements that together show how different cleaning methods can impact the anti-reflective coating of PV modules: visual inspection and qualitative reflection evaluation, reflection measurement, power measurement at standard test conditions (STC) and electroluminescence (EL) images. Lippke says that on their own, power measurements would be insufficient to reveal the consequences of any cleaning-related damage to the module coating over time; the reflection inspection and measurement provide a more visual representation of any coating degradation and any evidence of issues such as tire tracks. The further use of EL images helps reveal any internal damage such as micro-cracks, although Lippke acknowledges that as most cleaning systems run on module frames, they are unlikely to be the cause of such damage if it is found.

Lippke says there is also a case for providing standardisation around brushes and cleaning fabrics. "It would be nice to have a variable less to worry about," he says. Further standardisation around these enhance the evaluation process for assessing different cleaning products and solutions, especially when used with other criteria such as data on the type of soiling.

Credit: PI Berlin

Standardised testing procedures are helping shed light on the impact of cleaning technologies on module performance

Conclusion

In the coming years, robotics cleaning will become more mainstream. Strøm says, "It is already happening, but wider adoption will be driven by the reduction in cost of robots as volumes increase and the technology continues to improve in performance. As it becomes more proven, it therefore becomes more bankable."

Another trend driving uptake of automated cleaning, Strøm and Korevaar agree, is the trend to competitive auctions, happening all over the world, from Spain to Chile. This has increased the importance of de-risking all aspects of projects, including O&M. ■