

Cleaning of PV Modules

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- **Overview about cleaning methods**
 - **Truck-mounted systems**
 - **Semi-automated devices**
 - **Fully automated devices**
 - **Portable robots**

- **Cost-of-ownership analysis**

- **Testing protocols**
 - **site specific testing**
 - **rating for cleaning devices**





Semi-Automated

Fully-Automated

Portable Robots

Overview about Cleaning Methods

Truck-mounted

Characteristics

- Brush attached to a truck which drives between the PV module rows
- Each machine has its own system for controlling the pressure of the brushes on the PV modules



BP Metalmeccanica S.r.l.

Pros

- + No additional construction needed
- + Labor in air-conditioned vehicle
- + Flexible application
- + Gaps, steps and different tilt angles of modules tables are not a problem

Cons

- Minimum row space necessary
- Not applicable in case of irregular ground conditions
- Risk of „touching” modules
- Fuel necessary

Truck Mounted

Semi-Automated

Fully-Automated

Portable Robots

Overview about Cleaning Methods

Semi-Automated

Characteristics:

- placed manually and temporary at the beginning of each PV module-mounting table
- The device then moves automatically in one direction



Whashpanel

Pros

- + No additional construction needed
- + Stays easily on track
- + Flexible application

Cons

- Two people required to operate the device
- Sensitive to obstructions within tables (space, steps and tilt)
- The first module of the row may be damaged in case of mis-handling

Truck Mounted

Semi-Automated



Fully-Automated

Portable Robots

Overview about Cleaning Methods

Fully-Automated

Characteristics:

- installed on each row of a PV system and stored at a parking station/position
- Can move along a single module table only
- Should be planned before final design of PV plant



Sol-Bright

Pros

- + No manual labor during normal operation
- + Low cost in operation
- + Daily cleaning possible – at night !
- + Low risk of mechanical module damage
- + Recharging battery via own solar panel (certain products)

Cons

- Higher initial costs
- (Additional construction needed)
- Sensitive to obstructions within table
- Unfavorable for short module tables

Truck Mounted

Semi-Automated

Fully-Automated

Portable Robots



Overview about Cleaning Methods

Portable Robots

Characteristics:

- up to one square meter in size
- move on the surface of PV modules
- Can operate autonomously or driven by remote control



Miraikik Inc. Miraikik Type 1

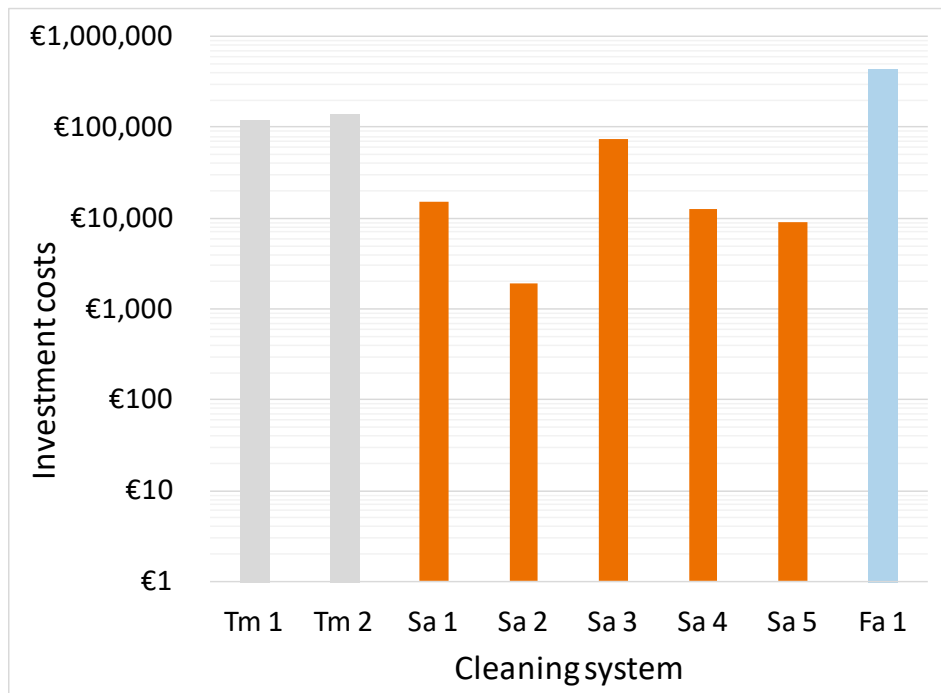
Pros

- + Favorably for trackers or roof top installations
- + Can work with different table dimension
- + Can be transported to different sites

Cons

- Limitation for certain module inclination
- Sensitive to obstructions within tables

Investments Costs



= manual
 = semi-automated incl. robot
 = fully automated

Real example:

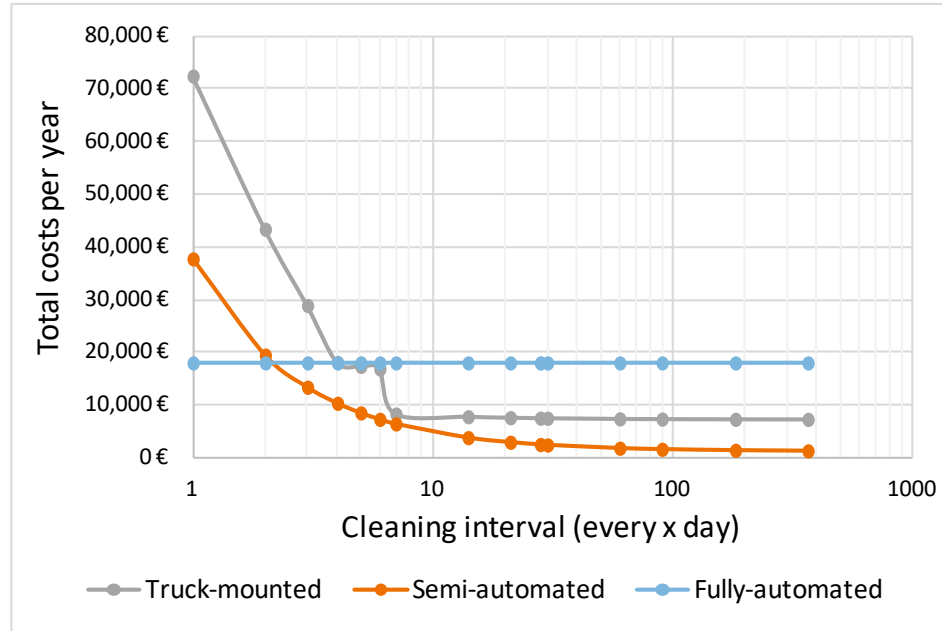
10 MWp PV power plant in India.

38,600 pcs. of 260Wp 60-cells modules.

System	Costs per operation	Costs for maintenance per year
Truck mounted	20 €	2 000 €
Semi-automated	100 €	200 €
Fully-automated	-	1 000 €

Operating costs base on labor costs in India.
Can be very different in other regions.

Costs per Year



Real example:

10 MWp PV power plant in India.

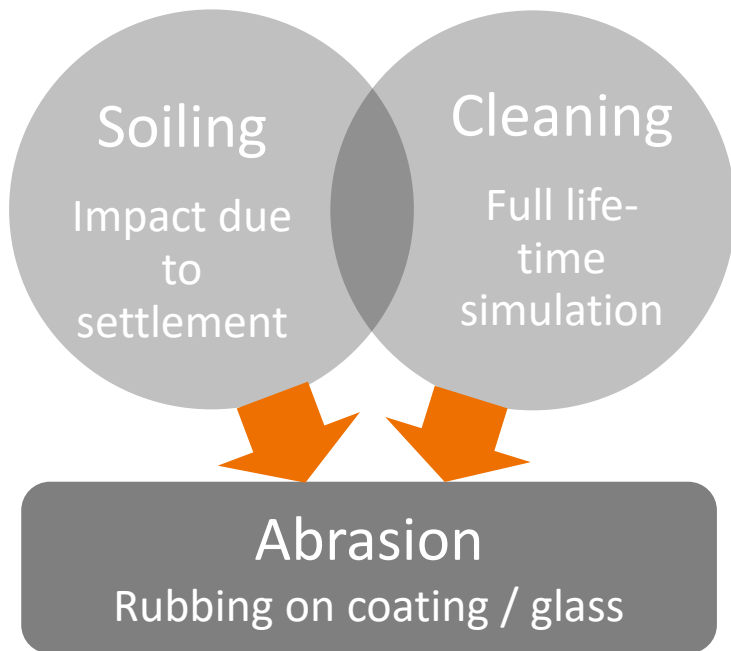
38,600 pcs. of 260Wp 60-cells modules.

Frequency of cleaning

- Determined by considering the soiling rate and the cleaning costs (both CAPEX and OPEX)
- Moderate soiling → truck-mounted or semi-automated
- Higher soiling rate → fully automated systems

Soiling, Cleaning and Abrasion

Module manufacturers should approve the cleaning system to avoid any warranty dispute.
Up to now no standard exists for testing the impact of soiling and cleaning on PV modules.



→ PI testing of cleaning device

Accelerated cleaning in order to simulate real the impact to the module

Customized cleaning procedure

Simulate the soiling and cleaning conditions of a specific power plant and the specific panel type.

Standardized cleaning procedure would be helpful.

Accelerated stress test

reproduce a defined number of years of operation

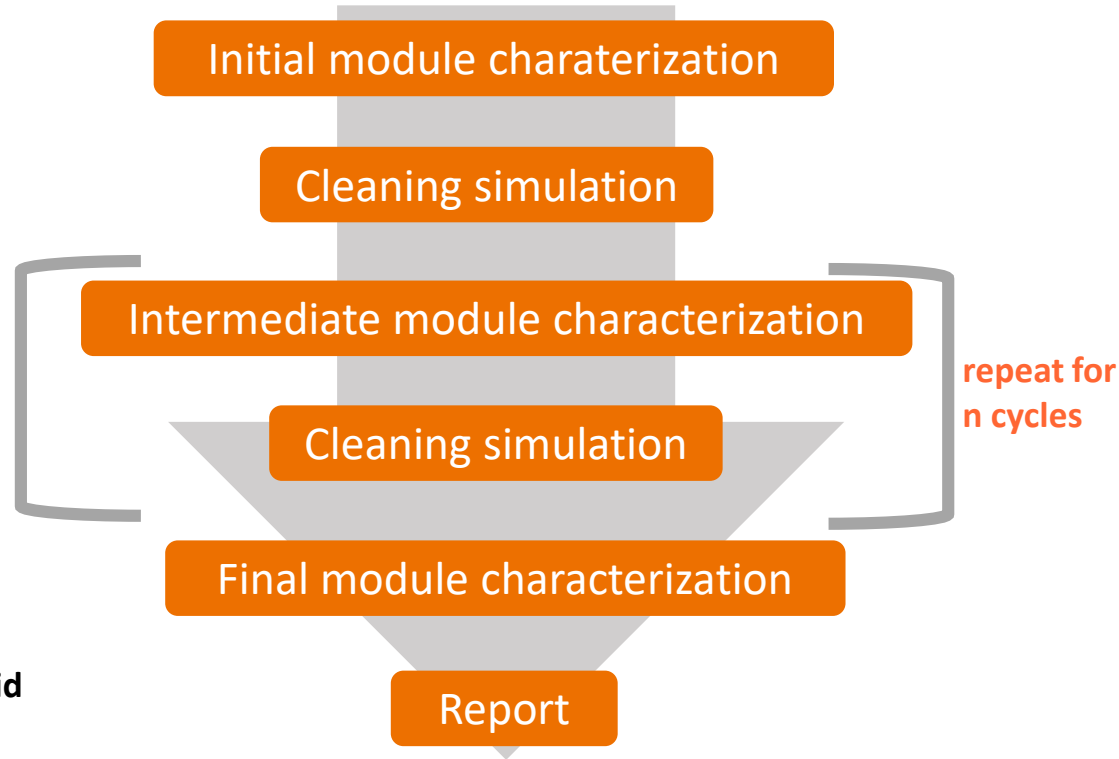
Testing conditions for specific power plant

- Cleaning device
- frequency
- Module types
- Soiling (sand type and amount)

Module characterization

- Reflection measurements
- Visual inspection
- Performance measurements
- electroluminescence

→ **Evaluation of the cleaning device only valid for a specific power plant**



Standardized Test Procedure for Cleaning Devices

For a general approval of cleaning devices, independent of a specific project, PI Berlin has developed an in-house **standardized lab test protocol**. This test procedure simulates **severe field** conditions:

- Simulation of cleaning every 3 days over 25 years
- Sand spread before every cleaning cycle
- 60% coverage for simulating sandstorm
- Test samples are not PV panels but solar glasses with ARC for PV modules
- glasses laminated on a dark back sheet
- Reflection measurements and visual inspection every 500 cycles
- Rating system for the final evaluation of the cleaning device

- Overview of cleaning methods: truck-mounted, semi-automated, fully automated, portable robots
- Costs of cleaning methods: for frequent cleaning fully automated systems have lowest CoO. However, long lifetimes need to be achieved which is not yet proven
- no standard procedure does exist for testing of cleaning devices. Therefore most tests get conducted project-specific with the respective cleaning device, module type and sand type
- PI has developed a standardized testing procedure for cleaning devices with a rating system