



WHITE PAPER

Soiling Losses On Bay Area Solar Arrays: What Research Says About Cleaning Frequency

What published research compiled by NREL says about solar soiling losses, how much cleaning recovers, and how Bay Area commercial owners can set a site-specific cleaning schedule.

Executive Summary

Dust, pollen, soot and bird droppings on a solar array cut its output. How much, and whether cleaning pays for itself, depends on the site. This paper summarizes the soiling research collected in NREL's *Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems, 3rd Edition* and turns it into a practical way for Bay Area commercial owners to set a cleaning schedule. Every figure below is quoted from that report, with the original study named.

Key Points

- **Soiling Costs Energy:** It "reduces the energy output of the PV array and can lead to localized hot-spot failures if the soiling is uneven." NREL/TP-7A40-73822 §5.7.1
- **Typical Daily Loss:** "Studies report about 0.05% reduction in output per day due to soiling." NREL/TP-7A40-73822 §5.7.1
- **Site Matters:** Reported rates range from 0.01%/day in a clean desert to 0.36%/day near heavy agriculture and up to 0.5%/day with large bird populations. NREL/TP-7A40-73822 §5.7.1
- **No Universal Schedule:** NREL recommends a local, site-specific cost-benefit analysis. NREL/TP-7A40-73822 §5.7.1

What Soiling Is

Soiling is any material that collects on module glass and blocks light. NREL notes that losses are about twice as high in the morning and evening as at midday, because the shadow cast by each dirt particle grows at high incident angles. Rain helps: heavy rains result in "a nearly complete cleaning effect," while light rains clean much less effectively "and can even increase soiling if dust then sticks to sparse water droplets." NREL/TP-7A40-73822 §5.7.1

Published Loss Ranges

Finding	Value	Study As Cited By NREL
Annual Losses Reported	4.3% to 7.5%; many around 6%/year	Literature summary
Typical Daily Loss	About 0.05%/day	Literature summary
Daily Rate, 186 Systems	0.051%/day	Study recounted by Naeem (2014)
Naeem Experiments	0.061%/day	Naeem (2014)
Heavy Agriculture Area	0.36%/day	Literature summary
Clean Desert Area	0.01%/day	Literature summary
Large Bird Populations	As high as 0.5%/day	Literature summary

How Much Cleaning Helps

For a system in Mesa, Arizona, with 1.91% annual soiling loss, Naeem (2014) simulated one annual cleaning reducing loss to 1.52%/year (-20%), two to 1.32%/year (-31%) and three to 1.20%/year (-37%). Naeem also concluded routine cleaning was not cost-effective for residential, commercial or utility plants in that study, with cleaning costs of \$0.25/m² to \$1/m² and about 1 liter/m² of water. NREL/TP-7A40-73822 §5.7.1 NREL adds that "where special conditions ... occur, cleaning will be required on a schedule that depends on the source and nature of the soiling."

Bay Area Factors

NREL lists soiling sources that may call for prevention or cleaning. Several are common at Bay Area commercial sites: construction dust (clean after nearby construction ends), pollen (clean after pollen season), bird populations, diesel soot near bus depots and city traffic, and industrial sources such as kitchen exhaust, where "a filter added to a fryer can reduce oil in kitchen exhaust air." NREL/TP-7A40-73822 §5.7.1

Building A Cleaning Schedule

Factor (NREL)	Effect On Interval
Cost Of Cleaning	Mobilization fee plus per-area cost; higher cost favors fewer cleanings
Soil Accumulation Rate	Faster soiling favors more frequent cleaning
Capacity Factor	Better solar resource, higher reward for cleaning
Value Of Power (\$/kWh)	Higher value, higher reward
Module Efficiency	Lower efficiency means more area cleaned for the same benefit

- Track Production Before And After Each Cleaning
- Inspect After Construction Nearby, Pollen Season And The Dry Season
- Treat Bird Droppings Promptly Because Uneven Soiling Risks Hot Spots
- Consider Condition-Based Cleaning Triggered By Monitoring

NREL notes cleaning "may be on a defined interval or 'condition based'," and that the frequency "may be seasonal, depending on local rainfall and dust characteristics." NREL/TP-7A40-73822 §5.7.1

Sources

- NREL et al., Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems, 3rd Edition, NREL/TP-7A40-73822, December 2018, §5.7.1 (citing Naeem 2014). <https://www.osti.gov/servlets/purl/1489002>

This paper summarizes published research for general information and is not legal advice. Requirements may change and vary by city; consult the current text, your local agency and qualified professionals.

About Window Cleaning Bay Area

Window Cleaning Bay Area provides commercial window cleaning, pressure washing and solar panel cleaning across the San Francisco Bay Area. Contact: grayson@windowcleaningbayarea.com