Sole4PV: towards the Optimization of Soiling Loss Mitigation for Large-Scale Photovoltaics

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Sole4PV (Soiling Live Estimation for Photovoltaics)

Project funded by the **Italian Ministry of University and Research** under the 2019 **«Rita Levi Montalcini» Program** for Young Researchers

SOiling Live Estimation for PhotoVoltaics

Agenda

- Introduction: Soiling definition and impact
- Motivation
- **NoSoilPV**: results
- **Sole4PV**: aims and ongoing work
- Conclusions and Future Work

ADVANCES IN PV Tech

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NoSoilPV

NoSoilPV: Novel Soiling Identification Logics for Photovoltaics
Awarded 2017 MSCA IF proposal (Agreement No. 793120)

Photovoltaic Soiling: definition

Deposition of dust, particle, dirt on the surface of PV modules.

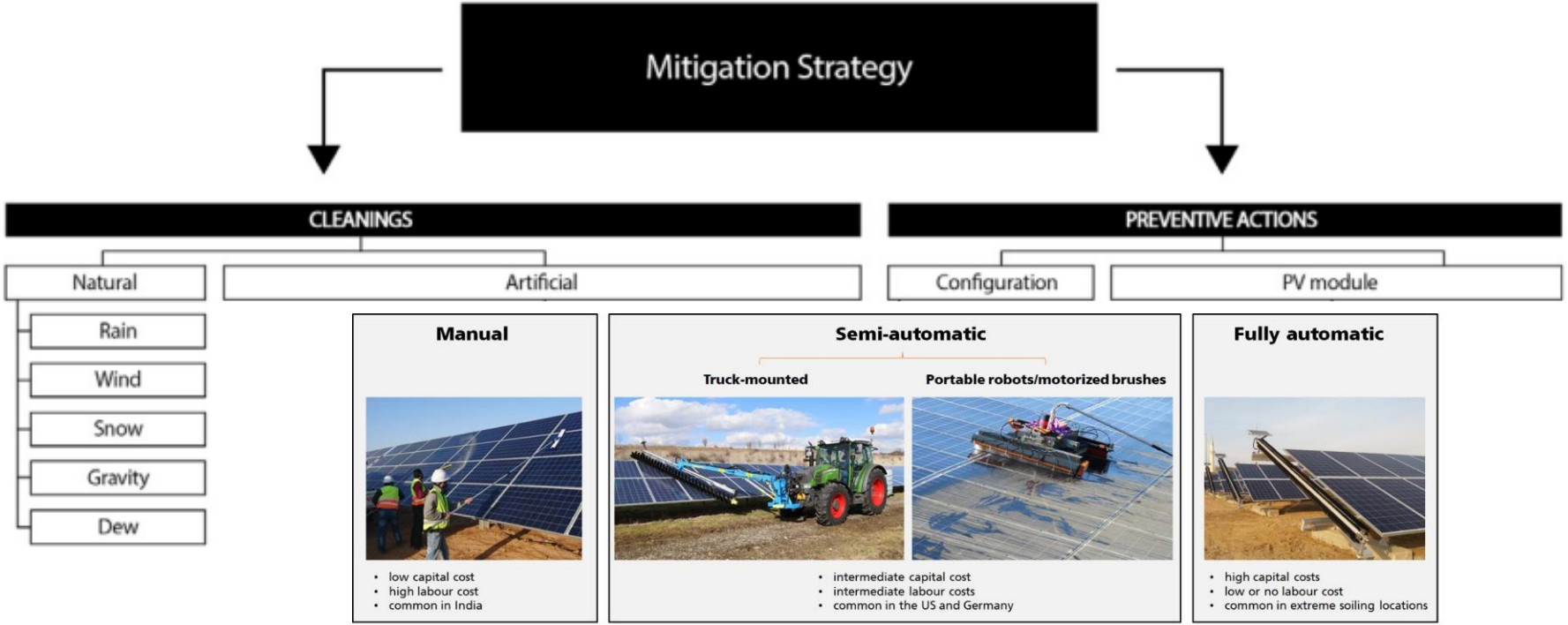
Soiling absorbs, reflects, scatters part of the incoming sunlight.

3-4 % of the global PV energy yield lost in 2018 because of soiling

➔ **4 to 7% loss** in 2023.

Photovoltaic Soiling

Differently from other losses, **soiling is reversible**.

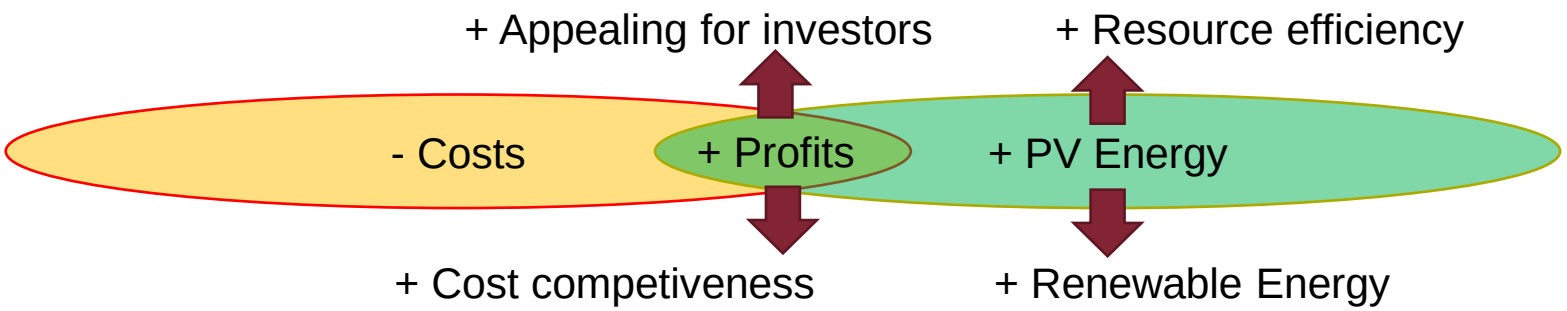


Ilse et al. “Techno-economical assessment of soiling losses in global solar energy production and mitigation strategies”, Joule (2019).
G. Bessa, et al., Monitoring photovoltaic soiling : assessment , challenges , and perspectives, iScience (2021). doi:10.1016/j.isci.2021.102165.

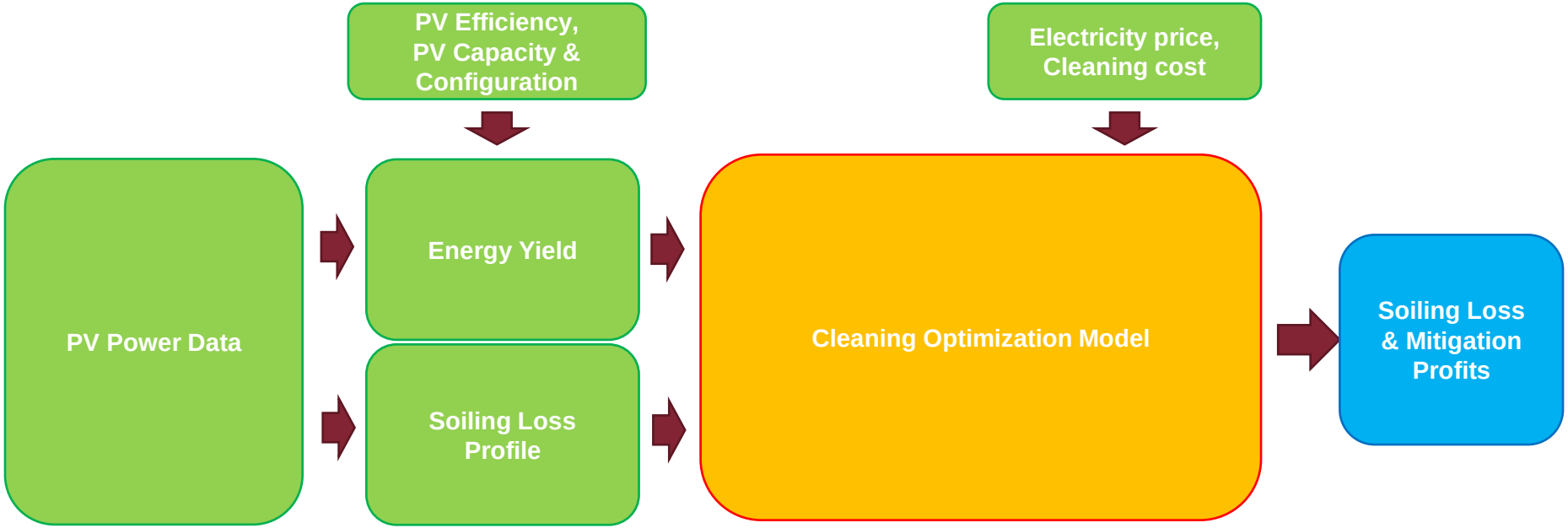
Photovoltaic Soiling: Research Question

1. **Cleanings have a cost ➔ + cleanings, + energy, + costs**
2. **Natural events (e.g. rainfalls) can clean soiling.**

Cleaning optimization ➔ max(cleaning profits - cleaning costs)



NoSoilPV


PV Efficiency, PV Capacity & Configuration
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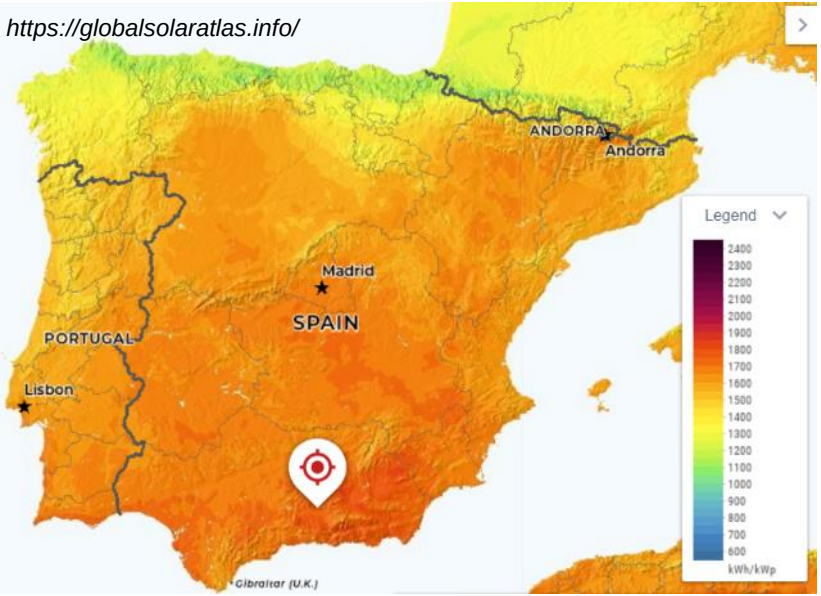
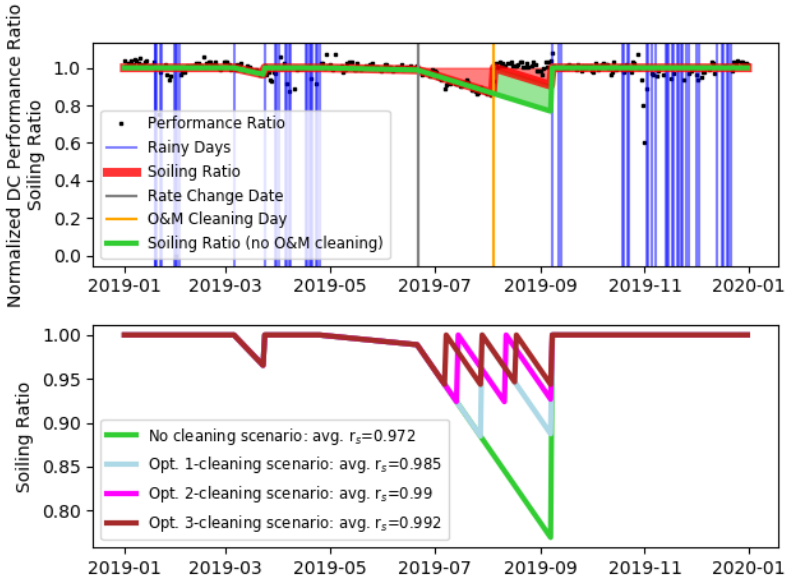
Methodology: Site



1 MW PV site in Granada, Spain

- Mono-crystalline Si
- 30˚ tilt angle, South orientation
- > 1700 kWh/kW AC energy yield
- AC and DC data for 2019

Methodology: Cleaning Optimization



*Soiling loss modelled to repeat every year**

- Performance ratio extracted from DC power of one string.
- Soiling profile extracted from performance ratio.
- Soiling rate change on June 22:
  - Before: -0.02 %/day
  - After: -0.28 %/day
- Cleaning performed by the O&M team on August 5.
- Maximum soiling extent was modelled:
  - Average loss: 2.8 %
  - Maximum loss: 23.1 % (end of summer)
- Various cleaning frequencies modelled: from 0 to 6 cleanings per year.

L. Micheli, et al., Economics of seasonal photovoltaic soiling and cleaning optimization scenarios, Energy. 215 (2021) 119018. doi:10.1016/j.energy.2020.119018.

* L. Micheli, et al., Photovoltaic cleaning optimization through the analysis of historical time series of environmental parameters, Sol. Energy. 227 (2021) 645–654. doi:10.1016/j.solener.2021.08.081.

Methodology: Economics Metrics

The Levelized Cost of Electricity (**LCOE**) quantifies the cost of producing a kWh of electricity. The lower, the better.

$$LCOE = \frac{Installation\ Costs + \sum Yearly\ O\&M\ Costs\ /Discount}{\sum Yearly\ Energy\ Yield\ /Discount}$$

The Net Present Value (**NPV**) is commonly used in the private sector to evaluate the profitability of an investment. The larger, the better.

$$NPV = -Installation\ Costs + \sum \frac{Yearly\ Revenues - Yearly\ O\&M\ Costs}{Discount}$$

Installation Costs (700 €/kW)

Yearly O&M Costs:
- Cleaning frequency
- Cleaning cost (**0.62 €/kW/cleaning**)

Yearly Energy Yield:
- AC Energy output
- Soiling Loss
- Degradation (-1 %/year)

Yearly Revenues:
- Yearly Energy Yield
- Electricity Price (**0.06 €/kWh**)

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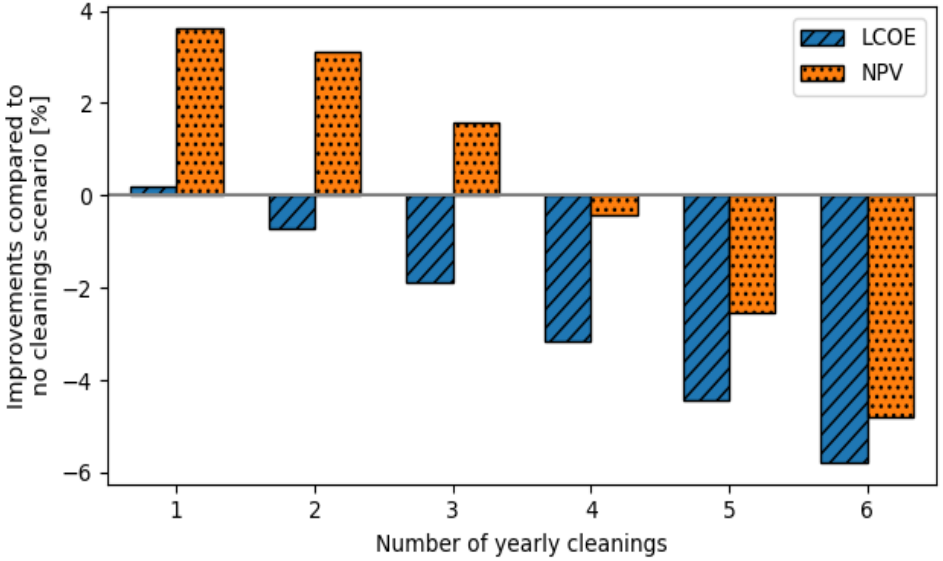
Results: Cleaning Frequency Optimization



- Both LCOE and NPV recommend 1 cleaning per year.
- Any number of cleanings up to 3 would be more profitable than no-cleaning.
- For LCOE, better no mitigation than cleaning more than once per year.

Positive improvement:
raise in NPV, drop in LCOE

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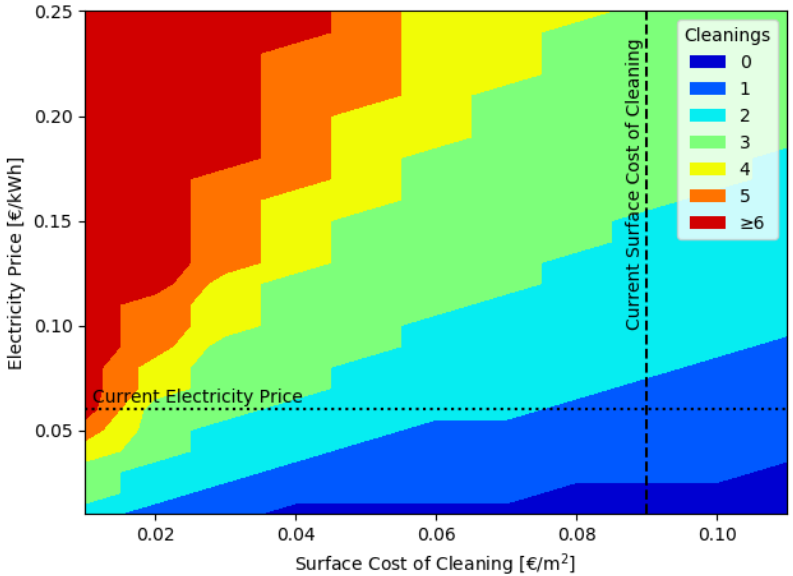

The optimal number of cleanings changes with the cleaning costs and the electricity price.

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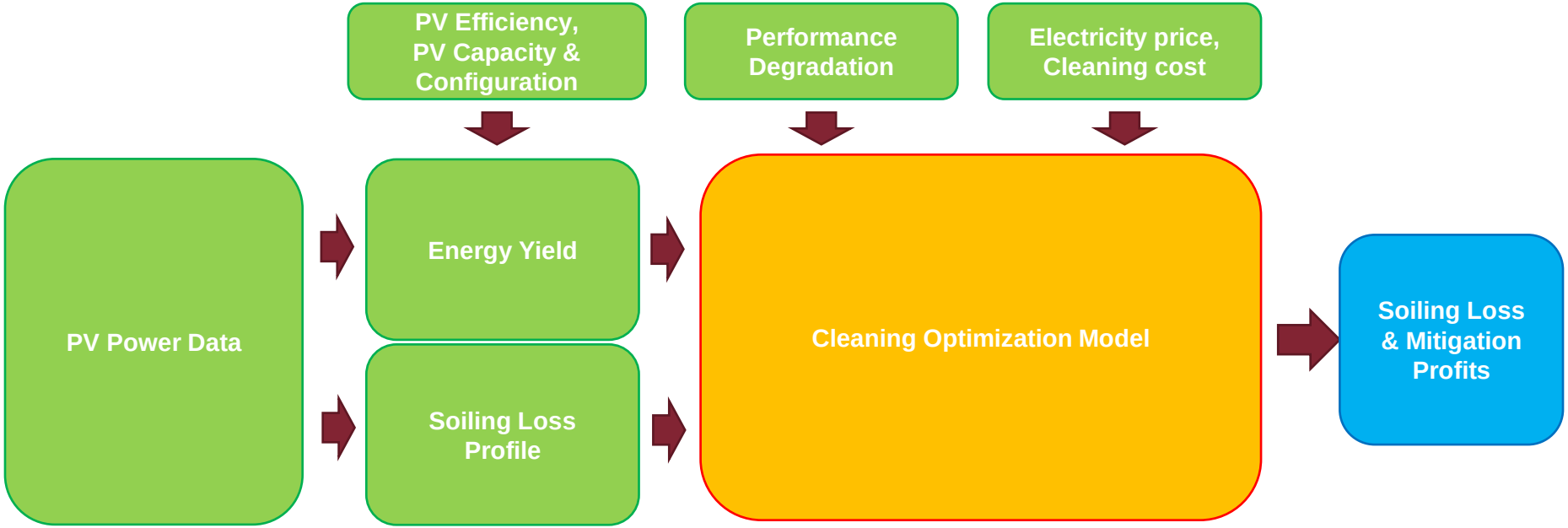
NoSoilPV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Results: Cleaning Frequency Optimization

The number of cleanings can be optimized every year.

Revenues increasing if:

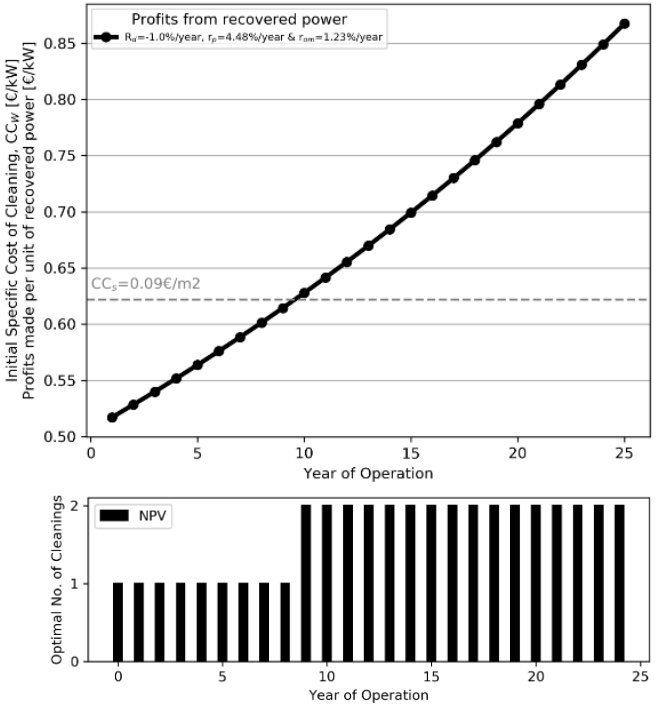
$$|R_D| < 1 - \frac{1 + r_{om}}{1 + r_p}$$

$$0.01 < 1 - \frac{1+0.01}{1+0.05}$$

$$0.01 < 1 - 0.96$$

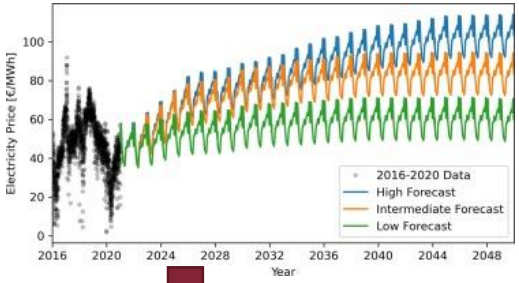
True

R_D: degradation rate
r_{om}: cleaning cost variability
r_p: electricity price variability



L. Micheli, et al., Photovoltaic cleaning frequency optimization under different degradation rate patterns, 166 (2020). doi:10.1016/j.renene.2020.11.044.

Sole4PV



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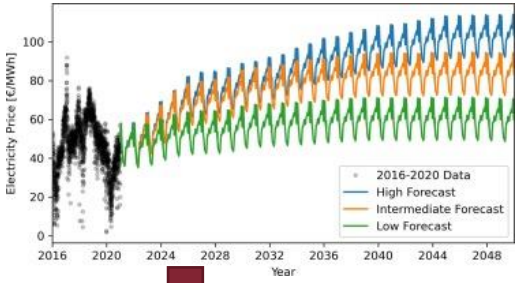

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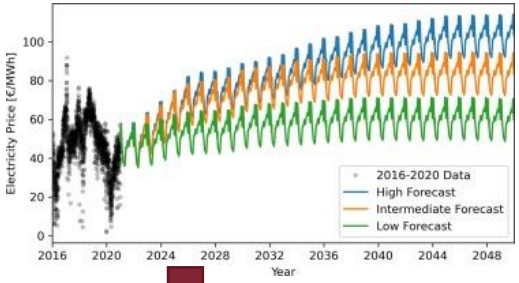

Irradiance, Temperature

Energy Yield

Environmental Parameters

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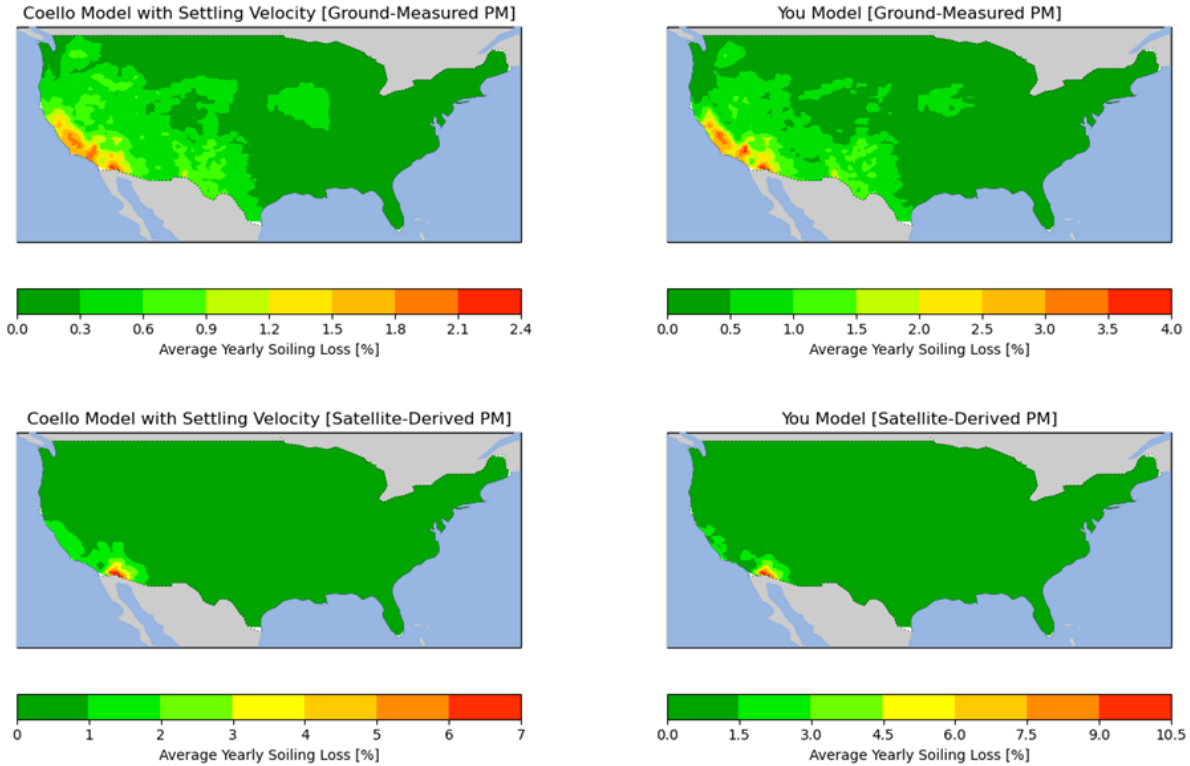
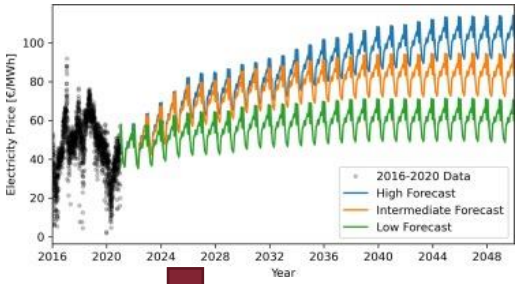
Sole4PV: Mapping



- Soiling models produce different estimates.
- These vary also depending on data in input.

L. Micheli, et al., Tracking Soiling Losses: Assessment, Uncertainty, and Challenges in Mapping, IEEE J. Photovoltaics. 12 (2022) 114–118. doi:10.1109/JPHOTOV.2021.3113858.

Sole4PV



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Inverter Clipping

Anti-Soiling Coatings

NoSoilPV: Findings

- The economics of soiling and cleanings was investigated.
- Different economic metrics will recommend different cleaning frequencies.
- The role of electricity price, cleaning cost and system degradation was investigated.

Ongoing Work: Sole4PV

- Soiling estimation and mapping will be improved.
- Realistic long-term electricity prices are considered:
  higher electricity prices will favour soiling mitigation
- Additional factors, such as clipping, are being analyzed.
- Further soiling mitigation techniques are being modelled.

Grazie mille!

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