
LEADING PV PERFORMANCE IMPROVEMENT SPECIALISTS

Cleaning Strategy Development
for Utility Scale PV Plants –
Local Soiling Impact

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inDust

USER WORKSHOP: The effect of Soiling on Solar Energy

Agenda

- Short intro to Alteso & PEAK
- Common O&M issues
 - Focus on soiling
- Main factors:
 - Geography (Europe & India)
 - Locations
 - Plant design
- Short term and long term soiling
- Economic considerations:
 - Cleaning schedules
 - Combined factors
- Strategy definition
- Conclusion



Alteso: Reach the Peak

Alteso is a green technology company and the leading performance improvement specialist.

We provide PV asset performance management to PV asset managers, owners and O&M companies with **Results-as-a-Service** in the form of digital analysis accompanied by personal support.

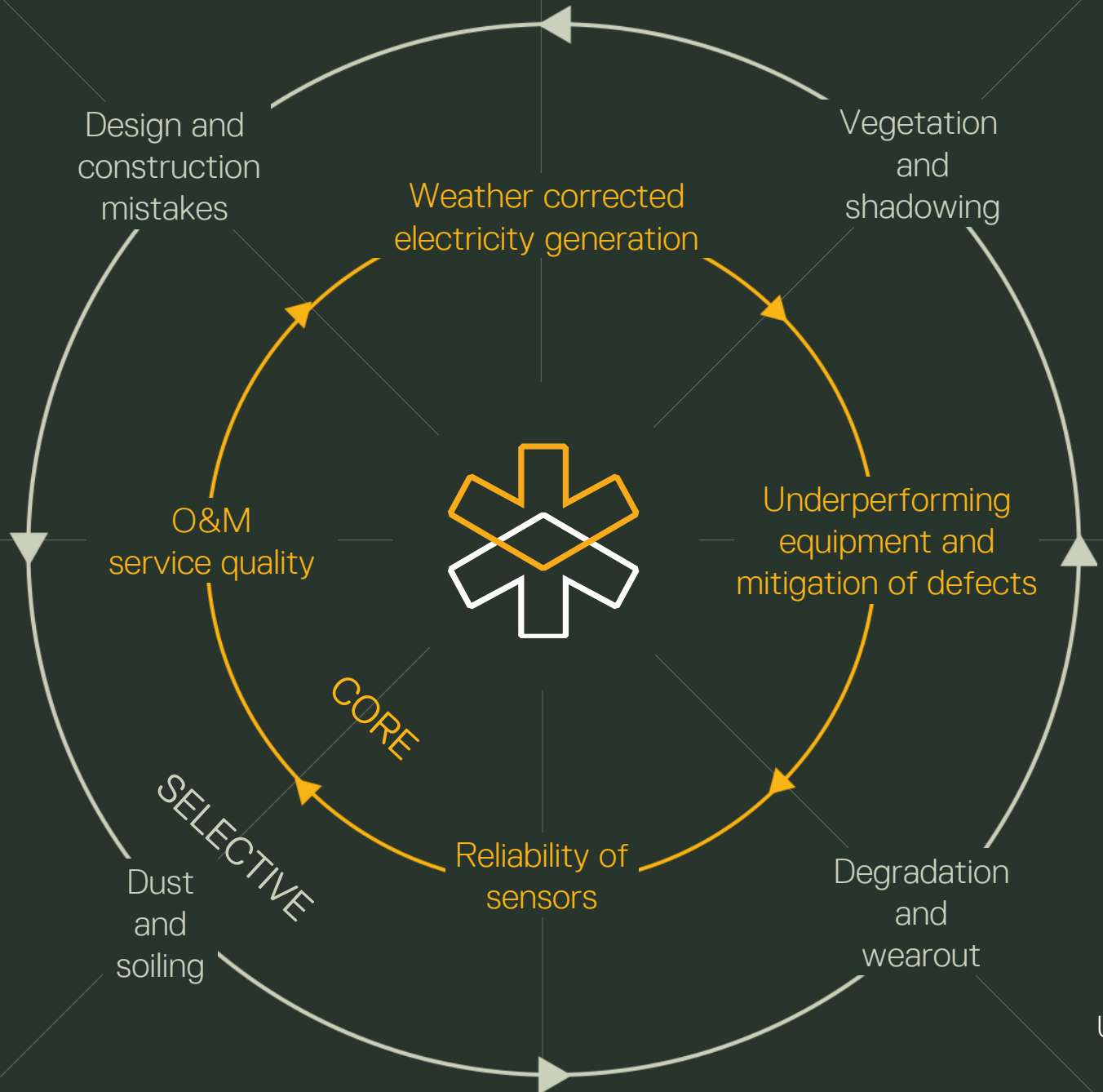
Our experience:

- Client coverage in 15 countries
- Over 1,700 MW of PV Plants analyzed
- Improved performance of up to 10%



PEAK – What?

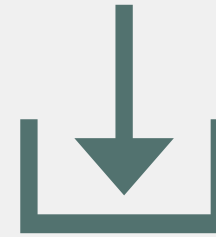
- Identifies **hidden** problematic areas of a PV asset
- Provides **concrete actions** for performance maximization
- Devises **strategies** for reducing operational & maintenance costs
- Simplifies integration through **Results-as-a-Service** via the web-based **PEAK COCKPIT**
- Remote – can be integrated in Monitoring & Asset Management System
No hardware or software installations



Used for iterative machine learning
3

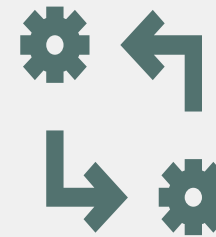


PEAK – How?



Collect

data in online (SCADA system) or offline modes (shared database)



Process

through filtering and mapping of every single PV plant unit



Analyse

using in-house developed analytics engine



Report

PEAK insights and translation into action (Results-as-a-Service)

Common O&M issues

Initial phase:

Start-up losses

- Incomplete installation
- Improper installation
- Infant component breakdown

Construction mismatch

- Wiring
- Load balance
- Peak shaving
- Local shadowing

Daily operation phase:

Small local failures

- Connectors / Fuses
- Broken modules
(due to grass cutting & cleaning)

O&M team performance

- Repair reaction time
- Implementation of procedures for preventive activities
- Internal education
- Service of sensor
- Control of external factors
(cleaning, cutting, repair)

Animal impact

- Rodents
- Birds
- Insects

Vegetation

- Grass / Trees

Soiling

- Optimum cost/benefit
(Peak shaving, self cleaning, etc.)
- Coating

Soiling, at plants in regions with a soiling issue and a cleaning schedule in place (albeit not optimized), **can have an impact on plant performance**, comparable to other issues, **ranging between 10-40%!**

Wear out phase:

Inverter wear out

- Capacitors
- Switches

Module degradation

- PID
- Thin film issues
- Backsheet
- Solderings in modules and connection boxes

Other equipment wear out

- Cables
(especially in sunny and/or humid climates)
- Connectors
- Mounting system

Geography: Europe & India



Europe:

- Cultivated land
- Seasonal changes
- High environment standards
- High OPEX

India:

- More desert areas
- Pollution
- Social circumstances
- Extreme climate
- Larger plant size

Locations

Agriculture

- Burning or clearing of straw
- Pollen and seed distribution
- Bush fires



Bush fire – Europe – before



....and after

Locations

- Desert/cultivated land



- Industrial zones/traffic



- Coastal regions



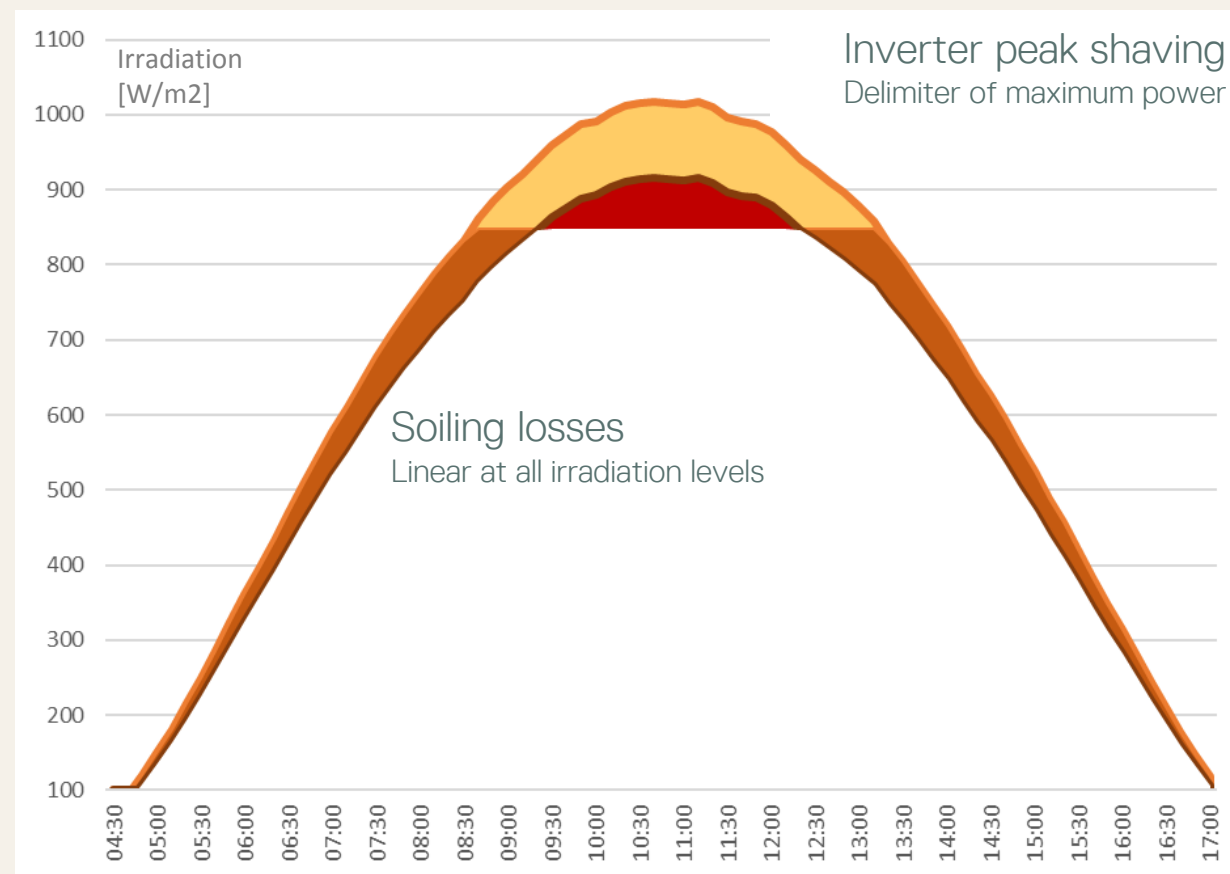
- Animal impact



Plant design

- Border with filter capabilities
- Module types:
 - Frameless, standard
 - Surface: glass, plastic, coated
- Tilt angle
- Inverter capacity (installed DC/AC)

Soiling loss	10,0%
DC/AC factor	120,0%
Inverter peak shaving losses	6,3%
Combined losses	11,7%
Effective soiling impact	5,4%



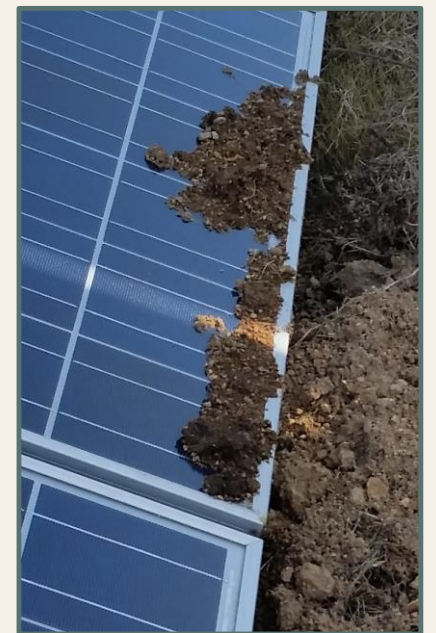
Short term

&

Long term soiling

- Snow & ice
- Thaw
- Soil (clay, sand, humus,...)
- Pollution particle (non adhesive)
- Vegetation impact (non adhesive)

- Pollution particle (adhesive)
- Vegetation impact (adhesive)
- Moss and fungi
- Scratches
- Bird droppings
- Remaining dirt from construction work



Economic considerations: cleaning schedules

Europe:

- As a standard 2-3 cycles per year
- Varies:
 - from country to country
 - according to specific plant location

Effective soiling impact combinations:



India:

- Larger variation
- Often bi-weekly to monthly

Economic considerations: cleaning

Initial Situation

Solution

Benefit

Example 1 (Europe) – Reduce labor costs – avoid routine physical checks

Difficult to quantify dirt and dust impact and cleaning expensive (250 MW asset - modules at 30° tilt)

Analysis of soiling intensity: targeted cleaning of specific strings and comparisons. Cleaning not necessary! Rain >1l/m²/min cleans sufficiently

- Cleaning costs eradicated

Example 2 – Optimize cleaning - location-optimized strategy guiding the cleaning team to critical areas

Cleaning costs of ~40k EUR per cycle for a 20 MW plant

Defined optimized schedule covering dirtiest areas approx. 35% of the plant

- Soiling losses reduced by -50%
- Performance improvement 1%
- Cleaning cost reduction of -60%

Example 3 – Optimize cleaning considering local labor costs, water supply and size of plants

Cleaning costs of ~4 EUR per 1,000 modules but limited water resources and huge plants 50 MW+

Defined optimized schedule considering water and time expenditure

- Soiling losses reduced by -30%
- Performance improvement 0,8%

Economic considerations: cleaning example 1



Economic considerations: cleaning

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Economic considerations: cleaning example 2

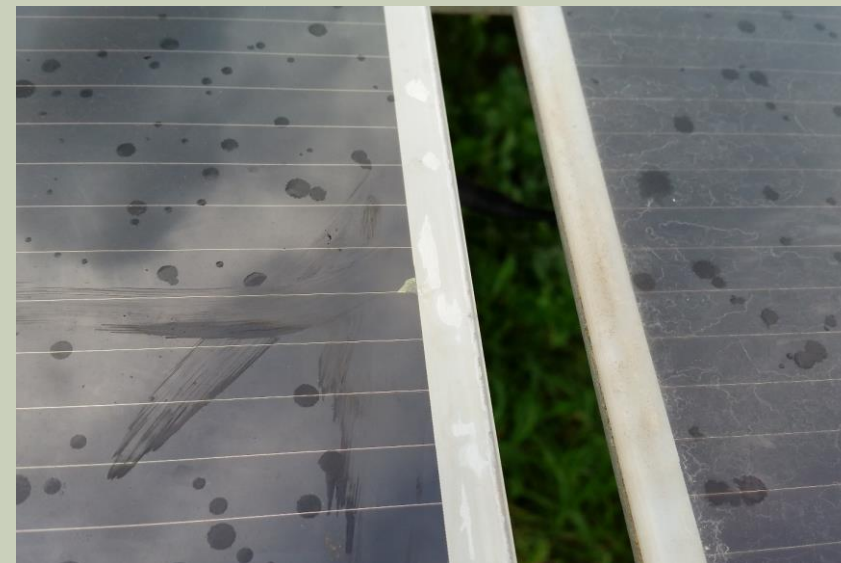
Reference Project	20MW
<u>TOTAL Time of cleaning (2 people), hours</u>	1367
-- Number of months for 2 people	8,5
Salary and personnel related costs per month, EUR	2500
Total costs per 1 worker	21 250
Minimum number of workers	2
TOTAL costs per 2 workers	42 500
Approx. total for 2 cycles per year	85 000

Optimized schedule = annual cleaning cost saving of approx. Euro 50,000

+ production loss mitigation of Euro 35,000 (175 MWh)

= TOTAL annual monetary benefit of Euro **85,000**

Cost/benefit analysis: annual fee for PEAK of Euro 30,000 (1,500/MW/year) justified
(just one element identified for the client)



Economic considerations: cleaning

Initial Situation

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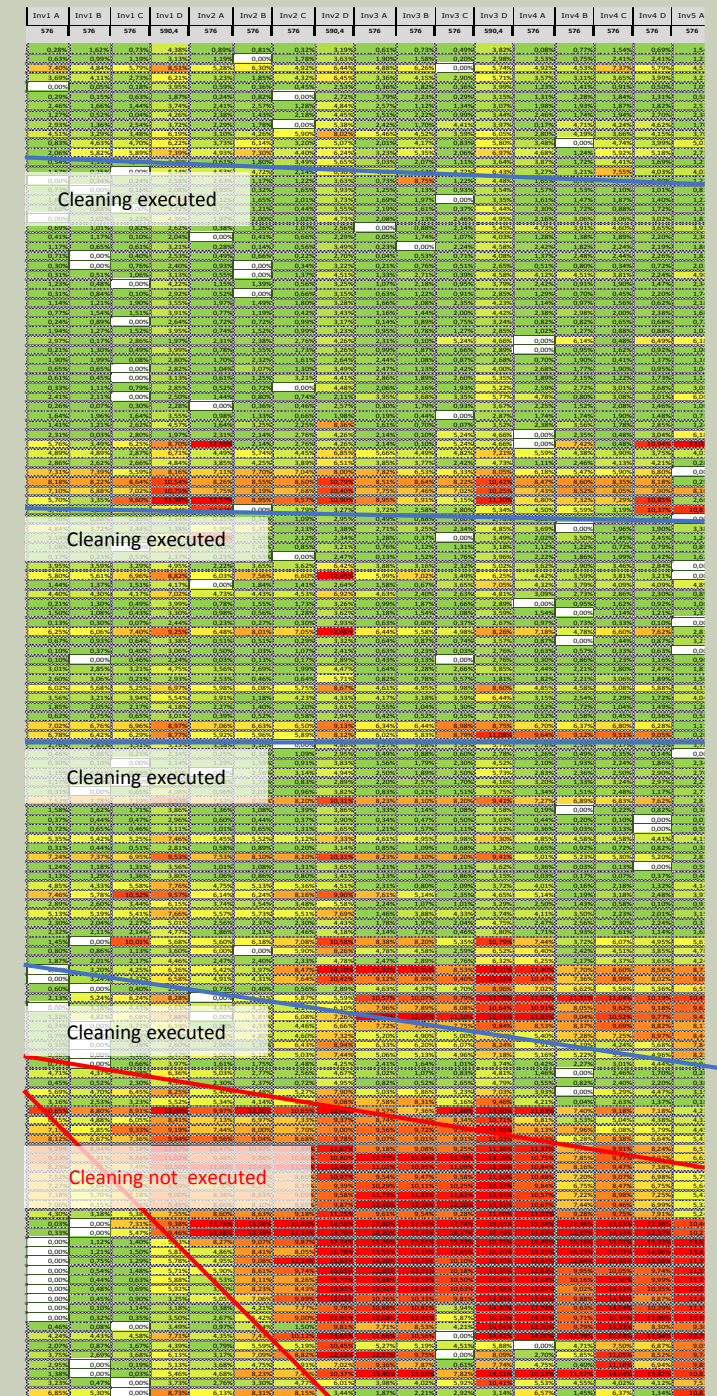
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Steps to quantifying soiling losses

- Collect and analyse historical data
- Identify all operative losses: big data mining
- Compensate to optimum possible production
- Analyze timeline: machine learning AI strategies
- Local soiling model for every unit: multi dimensional model
- Isolate soiling loss for every unit
- Summarize
- Generate parameter for extrapolation
- Extrapolate impact for optimum cleaning including cost/benefit



Strategy definition

Day	M_53.01	M_53.02	M_53.03	M_53.04	M_53.05	M_53.06	M_54.01	M_54.02	M_54.03	M_54.04	M_54.05	M_54.06	M_55.01	M_55.02	M_55.03	M_55.04	M_55.05	M_55.06	M_56.01	M_56.02	M_56.03
01.12.2018	-0,08%	-1,04%	-0,63%	-0,65%	-0,95%	0,10%	1,42%	2,46%	1,56%	1,51%	0,84%	1,01%	2,61%	1,80%	-4,42%	-0,15%	1,54%	1,60%	1,93%	1,26%	-0,26%
02.12.2018	-0,35%	-6,30%	-1,14%	-6,35%	1,02%	-5,27%	-4,87%	1,17%	-0,07%	-3,27%	2,26%	-2,91%	1,02%	0,56%	0,27%	0,11%	-1,94%	-6,39%	-1,11%	-0,41%	-6,52%
03.12.2018	0,41%	-0,46%	0,30%	-0,70%	0,64%	-0,94%	0,37%	-1,95%	0,26%	-0,59%	0,39%	0,71%	0,89%	0,64%	0,41%	0,50%	0,08%	-0,01%	-0,41%	-0,14%	-0,11%
04.12.2018	0,41%	-0,46%	0,30%	-0,70%	0,64%	-0,94%	0,37%	-1,95%	0,26%	-0,59%	0,39%	0,71%	0,89%	0,64%	0,41%	0,50%	0,08%	-0,01%	-0,41%	-0,14%	-0,11%
05.12.2018	1,97%	2,17%	2,40%	2,75%	2,32%	2,33%	2,06%	2,51%	1,84%	2,87%	2,09%	3,37%	2,73%	2,16%	2,16%	1,99%	2,55%	2,66%	2,31%	3,29%	3,44%
06.12.2018	1,57%	1,69%	1,98%	2,05%	2,03%	2,10%	1,41%	1,85%	1,26%	1,81%	1,29%	2,36%	1,05%	1,28%	1,07%	1,42%	1,68%	2,00%	1,46%	2,13%	0,79%
07.12.2018	1,06%	1,13%	1,39%	1,68%	1,35%	1,20%	1,03%	1,86%	0,90%	1,71%	1,24%	2,48%	1,29%	0,92%	0,57%	1,06%	1,08%	1,29%	0,01%	1,76%	1,42%
08.12.2018	-0,51%	-0,71%	-0,22%	-0,40%	-0,18%	-0,74%	-0,69%	0,26%	-0,82%	-0,40%	-0,41%	-0,02%	-0,77%	-0,96%	-0,95%	-0,94%	-0,77%	-0,18%	-0,61%	-0,14%	-0,31%
09.12.2018	-0,51%	-0,71%	-0,22%	-0,40%	-0,18%	-0,74%	-0,69%	0,26%	-0,82%	-0,40%	-0,41%	-0,02%	-0,77%	-0,96%	-0,95%	-0,94%	-0,77%	-0,18%	-0,61%	-0,14%	-0,31%
10.12.2018	1,04%	1,35%	1,31%	1,78%	1,38%	1,55%	1,36%	2,59%	1,14%	1,78%	1,53%	2,04%	-0,60%	-0,06%	-0,24%	0,03%	0,57%	0,65%	0,49%	0,98%	0,73%
11.12.2018	1,01%	0,92%	1,12%	4,91%	4,38%	4,38%	1,98%	3,19%	1,59%	1,85%	1,68%	2,22%	3,62%	3,71%	4,15%	4,34%	2,44%	2,15%	1,76%	2,39%	0,89%
12.12.2018	-1,96%	1,68%	1,84%	2,14%	2,02%	1,65%	1,34%	0,74%	1,05%	1,56%	1,18%	0,97%	1,05%	1,65%	1,83%	1,50%	1,52%	1,65%	1,20%	1,90%	1,61%
13.12.2018	1,19%	1,24%	1,36%	2,01%	1,77%	1,00%	0,85%	0,75%	0,85%	1,43%	1,35%	0,85%	0,77%	1,16%	1,44%	1,15%	1,02%	1,18%	0,82%	1,34%	1,41%
14.12.2018	0,74%	0,79%	0,91%	1,56%	1,32%	0,55%	0,40%	0,28%	0,40%	0,97%	0,90%	0,40%	0,31%	0,71%	0,98%	0,69%	0,57%	0,72%	0,37%	0,85%	0,95%
15.12.2018	-0,78%	-0,60%	-0,68%	0,10%	-0,32%	-0,50%	-0,65%	0,23%	-0,53%	-0,63%	-0,48%	-1,10%	-0,91%	-0,32%	-0,10%	-0,11%	-0,71%	-0,78%	-0,98%	-0,60%	-0,34%
16.12.2018	-0,80%	-0,62%	-0,70%	0,09%	-0,33%	-0,52%	-0,66%	0,22%	-0,54%	-0,65%	-0,50%	-1,12%	-0,92%	-0,34%	-0,11%	-0,12%	-0,73%	-0,80%	-0,99%	-0,62%	-0,35%
17.12.2018	-0,82%	-0,62%	-0,54%	-0,10%	-0,38%	-0,45%	-0,39%	0,16%	-0,36%	-0,20%	-0,41%	-0,36%	-0,69%	-0,32%	-0,09%	-0,12%	-0,44%	-0,21%	-0,76%	-0,11%	-0,11%
18.12.2018	-0,82%	-0,62%	-0,54%	-0,10%	-0,38%	-0,45%	-0,39%	0,16%	-0,36%	-0,20%	-0,41%	-0,36%	-0,69%	-0,32%	-0,09%	-0,12%	-0,44%	-0,21%	-0,76%	-0,11%	-0,11%
19.12.2018	-0,01%	-0,16%	0,14%	0,43%	0,14%	-0,67%	0,19%	-0,83%	0,44%	0,26%	0,25%	-0,09%	-1,90%	-1,21%	-1,19%	-1,50%	-1,16%	-1,29%	-1,64%	-1,37%	-1,47%
20.12.2018	0,70%	0,62%	0,93%	1,11%	1,14%	0,98%	0,81%	0,90%	1,18%	1,16%	1,43%	1,43%	-1,29%	-0,35%	-0,29%	-0,35%	0,06%	0,26%	-0,11%	0,52%	0,85%
21.12.2018	1,03%	0,82%	1,32%	1,23%	1,55%	1,03%	1,21%	1,24%	1,52%	1,12%	1,35%	1,58%	0,24%	0,67%	0,77%	0,55%	0,49%	0,47%	0,54%	0,78%	1,07%
22.12.2018	1,03%	0,82%	1,32%	1,23%	1,55%	1,03%	1,21%	1,24%	1,52%	1,12%	1,35%	1,58%	0,24%	0,67%	0,77%	0,55%	0,49%	0,47%	0,54%	0,78%	1,07%
23.12.2018	1,98%	1,83%	2,27%	2,43%	2,40%	1,98%	2,41%	2,28%	2,39%	2,20%	2,28%	2,67%	1,33%	1,53%	1,76%	1,77%	1,47%	1,60%	1,76%	2,04%	1,97%
24.12.2018	-1,37%	0,15%	0,35%	0,82%	-1,78%	0,28%	-2,85%	-3,06%	-2,05%	-2,10%	-2,13%	-2,14%	-2,88%	-2,31%	-2,43%	-2,73%	-2,68%	-2,80%	-2,63%	-2,79%	-2,31%
25.12.2018	-2,04%	-2,21%	-1,62%	-1,44%	-1,40%	-2,12%	-2,14%	-3,44%	-2,23%	-2,53%	-2,42%	-2,63%	-2,65%	-2,39%	-2,24%	-2,29%	-2,30%	-2,31%	-2,05%	-2,51%	-2,37%
26.12.2018	-2,04%	-2,41%	-2,09%	-1,65%	-1,71%	-2,00%	-2,05%	-3,44%	-2,23%	-2,53%	-2,42%	-2,63%	-2,65%	-2,39%	-2,24%	-2,29%	-2,30%	-2,31%	-2,05%	-2,51%	-2,37%
27.12.2018	-2,02%	-2,37%	-1,50%	0,15%	-0,04%	0,97%	1,06%	-3,31%	0,23%	-2,60%	-0,22%	-2,14%	-2,14%	-2,41%	-2,16%	-2,36%	-2,59%	-2,40%	-2,50%	-2,67%	-2,14%
28.12.2018	1,86%	2,47%	1,86%	-1,87%	1,53%	1,48%	1,63%	2,54%	1,40%	1,65%	1,67%	-2,44%	-1,50%	1,73%	1,83%	-0,21%	1,93%	2,04%	2,09%	-8,41%	2,20%
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30.12.2018	1,12%	2,36%	1,76%	2,03%	1,59%	1,25%	1,43%	0,63%	0,77%	0,60%	0,39%	1,86%	0,56%	1,53%	-0,90%	1,42%	1,73%	1,65%	0,23%	1,90%	1,94%
31.12.2018	0,23%	0,82%	0,27%	0,20%	-0,04%	-0,27%	-0,18%	0,64%	-0,62%	-0,59%	-0,49%	-0,17%	-0,60%	-0,19%	-0,31%	-0,22%	-0,15%	-0,21%	-0,09%	-0,16%	-0,02%
01.01.2019	-0,60%	-0,07%	-1,35%	-1,54%	-5,33%	-1,06%	-1,21%	-2,21%	-2,24%	-1,77%	-2,02%	-2,19%	-1,61%	-5,23%	-1,73%	-2,95%	-0,99%	-1,02%	-0,84%	-1,91%	-0,95%
02.01.2019	-0,60%	-0,48%	-0,73%	-0,81%	-0,54%	-1,11%	-0,86%	-1,14%	-1,78%	-1,73%	-1,66%	-1,96%	-0,97%	-0,42%	-0,59%	-0,62%	-1,31%	-1,55%	-1,42%	-1,59%	-0,94%
03.01.2019	-0,48%	-0,27%	-2,92%	-3,53%	-4,19%	-2,15%	-1,90%	-2,16%	-1,51%	-2,22%	-2,55%	-3,03%	0,01%	0,01%	0,25%	-0,07%	-0,30%	0,21%	0,78%	0,56%	-0,56%
04.01.2019	-0,48%	-0,27%	-2,92%	-3,53%	-4,19%	-2,15%	-1,90%	-2,16%	-1,51%	-2,22%	-2,55%	-3,03%	0,01%	0,01%	0,25%	-0,07%	-0,30%	0,21%	0,78%	0,56%	-0,56%
05.01.2019	-0,48%	-0,27%	-2,92%	-3,53%	-4,19%	-2,15%	-1,90%	-2,16%	-1,51%	-2,22%	-2,55%	-3,03%	0,01%	0,01%	0,25%	-0,07%	-0,30%	0,21%	0,78%	0,56%	-0,56%
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07.01.2019	-0,48%	-0,27%	-2,92%	-3,53%	-4,19%	-2,15%	-1,90%	-2,16%	-1,51%	-2,22%	-2,55%	-3,03%	0,01%	0,01%	0,25%	-0,07%	-0,30%	0,21%	0,78%	0,56%	-0,56%

Guide cleaning team to dirtiest areas first

Cleaning not on time

Strategy definition continued

Examples:

INV	Dirty Date	Dirty %	Clean Date	Clean %	Soiling loss %
INV-01	11-Apr-17	9.79%	12-Apr-17	2.95%	6.84%
INV-02	10-Apr-17	8.60%	11-Apr-17	2.13%	6.47%
INV-03	11-Apr-17	10.37%	12-Apr-17	4.37%	6.00%
INV-04	10-Apr-17	8.20%	11-Apr-17	1.95%	6.25%

					IRR→	5.85	5.66	5.71	5.76	5.41	5.21	5.83	5.96	6.03	5.87	5.81	5.82	5.77	5.81	5.76	5.63	5.75	5.76	5.42	5.48	5.51	5.63	5.38	4.83	5.71	5.69	5.59	5.23	5.11	5.27	5.23	5.07	5.46	5.54	5.46	5.67	5.66	5.68
Sr.No	INV	Capacity	Best non0	Worst non 100%	AVG	1-Apr-17	2-Apr-17	3-Apr-17	4-Apr-17	5-Apr-17	6-Apr-17	7-Apr-17	8-Apr-17	9-Apr-17	10-Apr-17	11-Apr-17	12-Apr-17	13-Apr-17	14-Apr-17	15-Apr-17	16-Apr-17	17-Apr-17	18-Apr-17	19-Apr-17	20-Apr-17	21-Apr-17	22-Apr-17	23-Apr-17	24-Apr-17	25-Apr-17	26-Apr-17	27-Apr-17	28-Apr-17	29-Apr-17	30-Apr-17	1-May-17	2-May-17	3-May-17	4-May-17	5-May-17	6-May-17	7-May-17	8-May-17
1	INV-01	552.24	0.84%	43.95%	6.15%	4.01%	4.62%	6.12%	7.09%	7.91%	9.25%	9.13%	9.25%	9.81%	10.51%	9.79%	2.95%	2.29%	2.55%	3.00%	3.32%	4.15%	5.14%	5.66%	5.70%	6.10%	6.86%	7.64%	3.95%	1.40%	1.22%	2.37%	3.63%	4.30%	4.44%	4.56%	6.02%	6.99%	6.71%	8.71%	8.62%	8.42%	9.01%
2	INV-02	552.96	1.11%	42.17%	5.90%	3.59%	4.33%	5.67%	7.07%	7.96%	9.37%	9.33%	9.56%	10.13%	8.60%	2.13%	2.39%	2.71%	2.96%	3.32%	3.66%	4.45%	5.44%	5.92%	5.94%	6.56%	7.38%	2.41%	2.44%	2.74%	2.73%	3.85%	5.29%	5.88%	5.86%	5.97%	7.42%	8.32%	7.81%	9.76%	9.82%	9.67%	10.15%
3	INV-03	552.96	2.22%	58.29%	7.79%	4.91%	5.42%	6.65%	7.91%	8.65%	10.07%	9.89%	10.09%	10.78%	11.55%	10.37%	4.37%	3.80%	4.03%	4.56%	4.89%	5.72%	6.63%	7.07%	7.24%	7.83%	8.55%	9.42%	5.56%	2.78%	2.66%	3.71%	4.09%	5.52%	5.49%	5.53%	6.99%	7.98%	7.55%	9.67%	9.64%	9.64%	10.35%
4	INV-04	552.96	-0.23%	10.12%	4.91%	3.18%	3.62%	5.03%	6.42%	6.98%	8.44%	8.53%	8.93%	9.64%	8.20%	1.95%	2.31%	2.57%	2.74%	3.12%	3.44%	4.25%	5.10%	5.37%	5.63%	6.25%	6.99%	1.43%	1.14%	1.77%	1.79%	2.74%	3.69%	4.41%	4.45%	4.57%	5.63%	6.96%	6.47%	8.46%	8.61%	8.47%	9.25%
5	INV-05	552.96	0.90%	60.97%	6.99%	5.07%	5.52%	6.73%	7.87%	8.74%	10.05%	9.85%	10.03%	10.56%	11.30%	10.30%	4.64%	4.03%	4.32%	4.76%	5.10%	5.95%	6.80%	7.28%	7.35%	8.14%	8.72%	9.57%	5.59%	3.14%	3.03%	3.97%	5.30%	5.73%	5.79%	5.87%	7.10%	8.24%	7.90%	9.92%	9.88%	9.83%	10.55%
6	INV-06	552.96	0.36%	92.37%	4.90%	2.68%	3.09%	4.54%	5.78%	6.37%	7.83%	7.88%	8.19%	8.83%	7.99%	1.94%	2.34%	2.62%	3.46%	4.37%	4.61%	4.77%	5.54%	6.13%	6.08%	0.48%	1.22%	1.19%	2.07%	3.59%	3.77%	3.73%	3.66%	3.77%	4.81%	6.23%	5.70%	7.65%	7.85%	7.68%	8.47%		
7	INV-07	551.88	-0.28%	19.07%	5.13%	2.67%	3.09%	4.39%	5.60%	6.34%	7.50%	8.02%	7.30%	9.44%	7.98%	4.57%	3.11%	3.47%	3.53%	3.88%	3.53%	1.58%	3.09%	4.81%	2.27%	6.33%	6.27%	1.57%	1.27%	1.22%	4.61%	2.09%	4.68%	4.16%	5.11%	3.82%	6.72%	7.79%	7.49%	9.42%	9.51%	9.31%	10.15%
8	INV-08	552.96	3.30%	45.69%	9.75%	6.15%	6.79%	8.03%	9.31%	10.11%	11.63%	11.34%	11.75%	12.34%	11.17%	4.76%	5.05%	5.52%	5.49%	5.80%	6.09%	6.91%	7.90%	8.38%	8.52%	9.29%	9.88%	4.67%	4.70%	4.87%	4.88%	5.74%	7.05%	7.84%	7.69%	7.79%	9.89%	10.07%	9.63%	11.55%	11.51%	11.29%	12.19%
9	INV-09	552.6	-1.38%	25.88%	2.66%	1.20%	1.46%	2.85%	3.93%	4.61%	5.83%	5.66%	6.08%	7.59%	7.73%	7.19%	0.91%	-0.35%	-0.06%	0.40%	0.64%	1.50%	2.39%	2.62%	2.81%	3.55%	4.22%	4.79%	0.94%	-0.89%	-0.93%	-0.13%	0.81%	1.54%	1.44%	1.56%	2.75%	4.18%	3.77%	5.70%	5.92%	5.85%	6.64%
10	INV-10	552.96	-0.71%	13.06%	3.36%	1.55%	2.04%	3.36%	4.62%	5.27%	6.74%	6.68%	7.12%	7.77%	6.42%	-0.24%	0.08%	0.49%	0.65%	1.03%	1.21%	2.07%	2.97%	3.21%	3.55%	4.36%	4.97%	-0.26%	0.58%	-0.01%	0.00%	0.81%	1.75%	2.54%	2.40%	2.49%	3.55%	4.91%	4.39%	6.42%	6.57%	6.37%	7.20%
11	INV-11	552.96	0.26%	64.07%	7.56%	3.52%	3.97%	5.28%	6.40%	7.32%	8.68%	8.54%	9.44%	9.72%	10.63%	10.47%	10.60%	4.60%	4.95%	5.38%	5.93%	6.59%	7.46%	7.95%	8.17%	15.87%	9.46%	10.16%	10.96%	9.43%	4.03%	4.91%	4.05%	4.61%	4.43%	4.55%	6.14%	7.12%	6.61%	8.65%	8.70%	8.76%	9.51%
12	INV-12	552.96	-0.68%	29.02%	4.31%	0.64%	1.09%	2.46%	3.69%	4.27%	5.71%	5.89%	6.31%	6.93%	7.47%	7.60%	7.83%	6.84%	0.23%	0.67%	0.82%	1.84%	2.70%	2.94%	3.39%	4.19%	4.90%	5.68%	6.34%	6.62%	3.63%	-0.68%	0.28%	0.92%	0.93%	0.97%	2.16%	3.57%	3.12%	5.12%	5.27%	5.12%	5.98%
13	INV-13	552.72	2.42%	47.09%	6.77%	3.18%	3.66%	5.01%	6.02%	7.15%	8.65%	8.49%	8.80%	9.46%	10.29%	10.48%	10.66%	4.43%	4.73%	5.15%	5.51%	6.40%	7.31%	7.71%	7.96%	8.75%	9.48%	10.19%	11.01%	9.20%	3.92%	4.75%	3.89%	4.42%	4.28%	4.29%	5.75%	6.82%	6.52%	8.49%	8.49%	8.57%	9.34%
14	INV-14	552.96	0.94%	45.89%	6.00%	2.09%	2.66%	3.87%	5.02%	5.93%	7.39%	7.38%	7.61%	8.10%	8.67%	8.76%	9.04%	7.19%	1.63%	2.07%	2.31%	3.30%	4.25%	4.65%	4.91%	5.81%	6.60%	7.59%	8.38%	8.01%	3.15%	1.05%	2.18%	2.56%	2.54%	3.96%	5.08%	4.74%	6.70%	6.71%	6.68%	7.33%	
15	INV-15	552.6	2.39%	64.15%	7.95%	3.25%	3.77%	5.04%	6.38%	7.32%	9.06%	8.82%	9.41%	9.40%	10.12%	10.10%	10.37%	10.59%	5.10%	3.49%	3.88%	4.87%	5.79%	6.20%	6.47%	7.31%	8.14%	9.23%	10.49%	9.62%	9.63%	7.53%	2.75%	3.47%	3.16%	3.20%	4.58%	5.78%	5.20%	7.17%	7.31%	7.32%	8.10%
16	INV-16	552.72	-0.87%	20.42%	3.50%	-0.83%	-0.32%	0.95%	2.31%	2.92%	4.14%	4.34%	4.59%	4.95%	5.27%	5.66%	5.97%	6.07%	5.88%	-0.58%	-0.27%	0.85%	1.79%	1.92%	2.33%	3.25%	3.97%	5.02%	5.87%	5.60%	5.69%	6.43%	4.36%	-0.30%	-0.30%	-0.35%	0.99%	2.33%	1.87%	3.64%	4.16%	4.03%	4.79%
17	INV-17	552.96	-2.88%	14.98%	3.25%	0.26%	0.75%	2.05%	3.47%	4.00%	5.57%	5.73%	6.05%	6.65%	7.29%	7.35%	7.55%	7.73%	1.92%	0.34%	0.61%	1.74%	2.64%	2.80%	3.22%	4.37%	4.94%	5.88%	6.37%	6.58%	6.57%	3.85%	-1.09%	-0.62%	-0.63%	-0.62%	0.77%	2.05%	1.58%	3.48%	3.84%	3.71%	4.60%
18	INV-18	552.96	1.43%	71.58%	9.14%	2.24%	2.83%	4.02%	5.47%	6.29%	7.74%	7.33%	7.69%	8.15%	8.94%	9.04%	8.95%	9.13%	9.03%	2.51%	2.88%	3.94%	4.97%	6.21%	6.60%	7.57%	9.06%	10.19%	11.38%	10.73%	10.82%	11.37%	8.66%	3.26%	3.03%	3.18%	4.51%	5.71%	5.16%	7.10%	7.32%	7.31%	8.01%
19	INV-19	558.36	-0.57%	19.86%	4.09%	1.90%	2.58%	3.73%	5.06%	5.93%	7.38%	7.01%	7.43%	3.53%	0.50%	0.82%	1.13%	1.37%	1.40%	1.65%	1.97%	2.70%	3.66%	3.96%	4.13%	4.97%	0.70%	1.06%	2.10%	1.89%	1.91%	2.90%	4.19%	4.51%	3.54%	3.59%	4.85%	6.04%	5.57%	7.42%	7.63%	7.45%	8.27%
20	INV-20	558.36	-0.53%	57.24%	4.91%	1.71%	2.43%	3.63%	5.00%	5.87%	7.28%	5.39%	0.15%	-0.25%	0.68%	0.96%	1.20%	1.38%	1.29%	1.61%	1.97%	2.67%	3.74%	3.50%	3.38%	-0.11%	0.29%	1.27%	2.23%	1.78%	1.79%	2.64%	3.84%	4.58%	4.15%	4.06%	5.40%	6.30%	5.65%	7.39%	7.64%	7.42%	8.04%
21	INV-21	558.72	0.12%	51.26%	6.61%	0.57%	3.08%	3.25%	5.34%	6.39%	7.92%	6.17%	0.82%	0.53%	1.17%	1.54%	1.74%	1.92%	1.86%	2.17%	2.32%	2.32%	3.68%	4.05%	4.00%	3.62%	0.74%	2.00%	2.86%	2.26%	5.67%	2.84%	6.75%	5.08%	5.21%	4.23%	5.95%	6.86%	6.23%	7.99%	8.17%	7.98%	8.65%
22	INV-22	558.48	-0.30%	91.03%	6.29%	2.88%	3.69%	5.01%	6.72%	7.05%	8.62%	6.80%	1.39%	0.94%	1.76%	2.01%	2.17%	2.35%	2.33%	2.61%	2.90%	3.58%	4.64%	4.49%	4.22%	0.72%	1.14%	1.96%	2.97%	2.74%	2.68%	3.55%	4.73%	5.52%	5.23%	5.17%	6.41%	7.31%	6.71%	8.49%	8.61%	8.44%	9.16%
23	INV-23	558.36	-0.94%	23.98%	4.49%	0.88%	1.51%	2.79%	4.20%	4.86%	6.35%	6.25%	6.68%	2.43%	-0.94%	-0.52%	-0.27%	-0.14%	-0.16%	0.23%	0.50%	1.28%	2.20%	2.49%	2.67%	3.62%	-0.74%	-0.42%	0.10%	0.91%	0.93%	1.77%	2.91%	3.72%	3.62%	3.65%	4.44%	6.16%	5.58%	7.49%	7.76%	7.53%	8.40%
24	INV-24	558.36	-1.93%	59.37%	5.24%	2.24%	2.89%	4.09%	5.55%	6.44%	8.14%	7.23%	0.54%	0.13%	0.97%	1.27%	1.40%	1.60%	1.46%	1.81%	2.22%	2.91%	3.94%	3.92%	3.93%	0.08%	0.50%	1.35%	2.40%	2.36%	2.24%	3.16%	4.36%	5.31%	4.93%	4.86%	6.03%	7.12%	6.33%	8.17%	8.36%	8.22%	8.92%
25	INV-25	558.36	0.42%	41.80%	5.05%	2.10%	2.84%	4.18%	5.65%	6.41%	7.85%	7.68%	8.09%	4.05%	0.44%	0.83%	0.91%	1.07%	1.08%	1.42%	1.88%	2.66%	3.66%	4.10%	4.23%	4.93%	0.69%	0.86%	1.97%	2.12%	2.21%	3.16%	4.55%	5.27%	5.22%	5.30%	6.65%	7.74%	7.17%	9.21%	9.26%	9.11%	9.95%
26	INV-26	558.36	-0.12%	43.45%	4.74%	2.36%	3.09%	4.37%	5.85%	6.63%	8.25%	7.86%	0.48%	0.12%	0.98%	1.28%	1.41%	1.56%	1.45%	1.76%	2.21%	2.88%	3.90%	3.97%	3.97%	0.21%	0.72%	1.52%	2.64%	2.62%	2.60%	3.51%	4.74%	5.54%	5.34%	5.22%	6.49%	7.47%	6.88%	8.79%	8.82%	8.62%	9.43%
27	INV-27	558.36	-0.67%	19.66%	3.67%	3.24%	3.83%	5.16%	6.76%	7.34%	8.76%	8.67%	8.91%	2.77%	1.43%	0.94%	1.17%	1.38%	1.38%	1.80%	3.22%	5.02%	5.68%	4.19%	4.37%	5.26%	0.45%	0.68%	1.76%	2.80%	3.21%	3.36%	4.38%	5.42%	5.31%	5.73%	6.54%	7.92%	7.31%	9.31%	9.46%	9.47%	10.33%
28	INV-28	558.48	0.03%	89.90%	7.52%	3.41%	4.23%	5.59%	7.11%	7.96%	9.46%	9.24%	0.38%	0.26%	1.21%	1.49%	1.63%	1.71%	1.87%	1.72%	2.20%	2.99%	3.94%	4.03%	3.99%	0.03%	0.50%	1.50%	2.75%	2.68%	2.67%	3.72%	5.00%	5.87%	5.64%	5.47%	7.00%	7.99%	7.16%	9.16%	9.24%	9.03%	9.75%
29	INV-29	558.36	-0.25%	48.35%	5.78%	3.22%	3.97%	5.33%	6.89%	7.21%	1.54%	1.35%	1.46%	1.76%	2.36%	2.61%	3.09%	2.98%	2.75%	2.73%	3.09%	3.70%	3.59%	1.37%	1.41%	2.21%	3.14%	4.16%	5.70%	5.47%	5.62%	6.69%	7.92%	8.98%	8.89%	8.8							



Conclusion

- Soiling is specific to:
 - plant location
 - plant design
 - O&M efficiency
- Cleaning schedules depend on:
 - soiling development
 - local climate
- Cleaning strategy optimization relies on:
 - accurate data
 - reliable soiling rate evaluation
 - cost/benefit analysis

Thank you for your attention!