

# Optimizing Photovoltaic Productivity for Private Homeowner Installations

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# Outline

- Green Energy
- Photovoltaic panels
- Goal
- Method
- Results
- Discussion

# Green Energy

- Energy generated from natural resources.
- Global efforts are aiming to increase electricity production from green energy.
- Efforts aim to reduce greenhouse gas emissions by 45% over the next decade, and to net zero emissions by 2050 [1].
- Israel's Ministry of energy goal is to produce 30% of the countries electricity demand from green energy by 2030 with an emphasis on solar energy [2].

[1] [https://www.gov.il/en/departments/general/renewable\\_energy](https://www.gov.il/en/departments/general/renewable_energy)

[2] <https://www.un.org/sustainabledevelopment/climate-change/>

# Homeowner installations

- The main resource for green energy in Israel is solar energy based on photovoltaic panels [1].
- The potential in Israel is to produce 46% of the electricity demand just by PVP systems that could be installed on rooftops [2].
- About 80% of those rooftops are residential buildings.

[1]<https://ourworldindata.org/renewable-energy>

[2][https://www.gov.il/BlobFolder/reports/potential\\_for\\_solar\\_production\\_on\\_existing\\_structures\\_jan\\_2020/he/climate\\_change\\_and\\_energy\\_efficiency\\_potential\\_for\\_solar\\_production\\_on\\_existing\\_structures\\_jan\\_2020.pdf](https://www.gov.il/BlobFolder/reports/potential_for_solar_production_on_existing_structures_jan_2020/he/climate_change_and_energy_efficiency_potential_for_solar_production_on_existing_structures_jan_2020.pdf)

# Photovoltaic panel (PVP) – Technology

- Photovoltaic panel converts light into electricity using solar cells [1].
- The solar cell absorbs the light and generates a charge, hence the clarity of the panel is mandatory.
- Accumulation of dust has a major effect on the PVP's efficiency and the electricity yield.

[1] <https://www.electrical4u.com/working-principle-of-photovoltaic-cell-or-solar-cell/>

# Optimal PV panel Installation factors

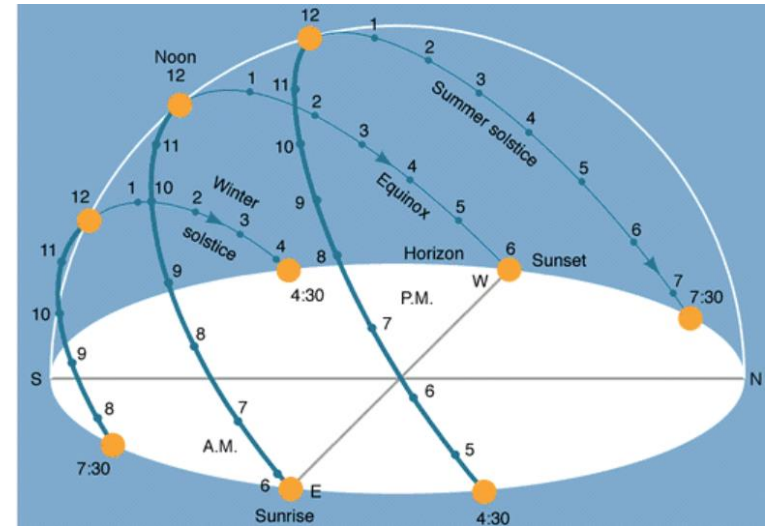
- Orientation – panels should face the equator:

north hemisphere (Israel) – facing south

- Inclination – Perpendicular to the sun

- Seasonal dependent[1]:

- During the winter the sun is low
- During the summer the sun is high



- In Israel, the optimal angle (fixed through the year) is about 26 degrees [2].

[1] <https://il.dsnsolar.com/info/how-to-figure-the-correct-angle-for-solar-pane-37645512.html>

[2] <https://www.engis.co.il/%d7%9e%d7%a2%d7%a8%d7%9b%d7%95%d7%aa-%d7%a1%d7%95%d7%9c%d7%90%d7%a8%d7%99%d7%95%d7%aa/9/>

# Yield vs. Aesthetics



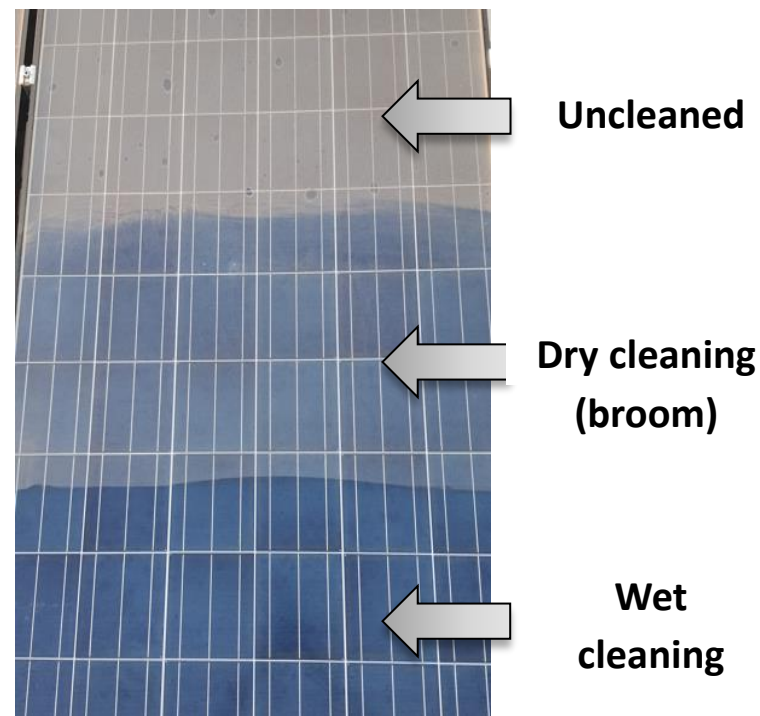
# Constrains – roof inclination





# Research Goal

- Homeowner PVP installation recommendations regarding:
  - Wet cleaning vs. broom cleaning
  - Dust accumulation rates based on the inclination angle
  - Cleaning rate yield impact
- Investigate the optimal inclination for homeowner installations
- Provide a tool for estimating the system's yield



# Research Method

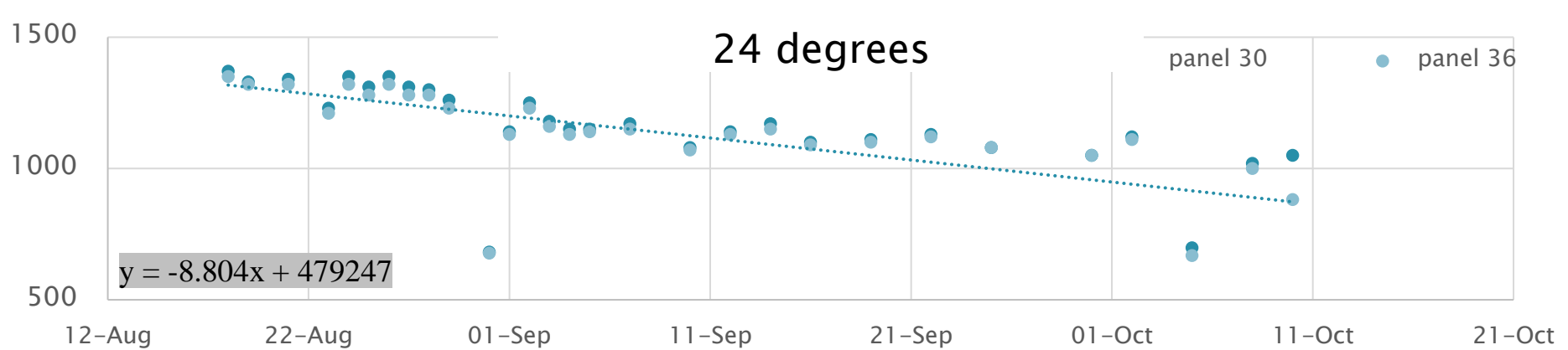
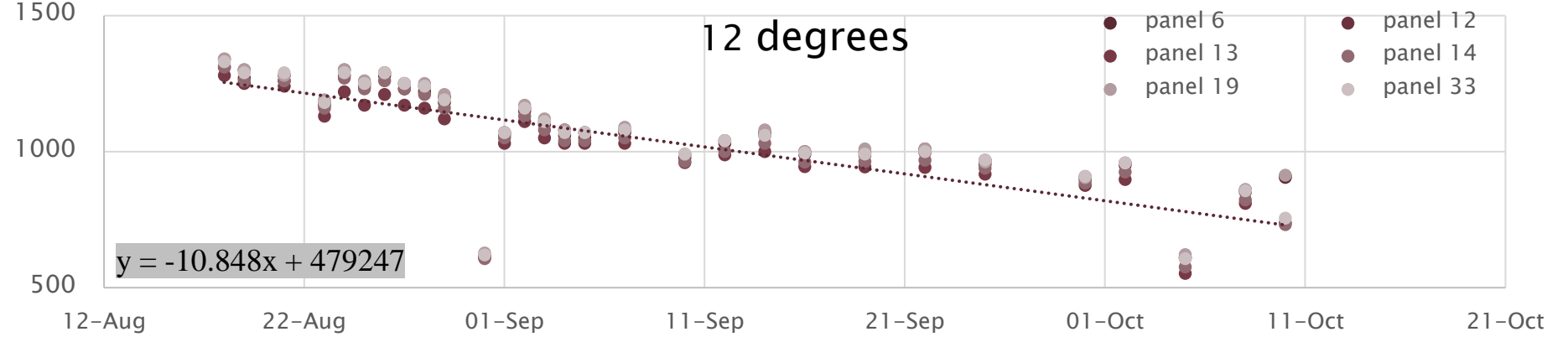
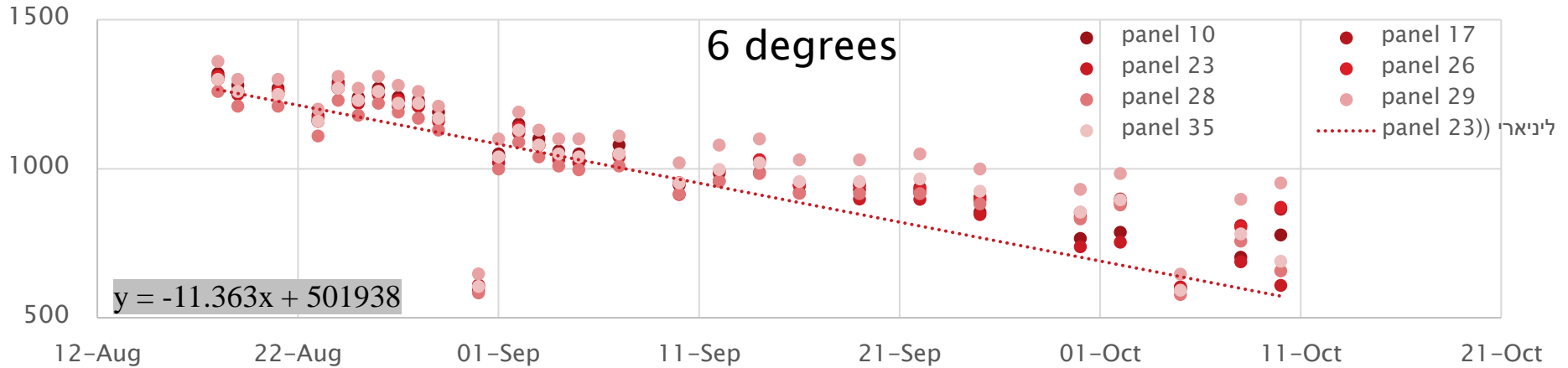
- PVP System description:
  - ❖ 13 Panels with a  $6^\circ$  inclination
  - ❖ 12 panels with a  $12^\circ$  inclination
  - ❖ 30 panels with a  $24^\circ$  inclination
- We used a clean PVPs as a reference for the daily optimal yield with the exclusion of weather condition effects
- Comparison between the PVP yield based on the PVP inclination
- Comparison between the PVP yield based on the PVP cleaning method
- Produce a yield curve based on image processing that predicts the PVP's yield

# Production yield vs. PVP inclination

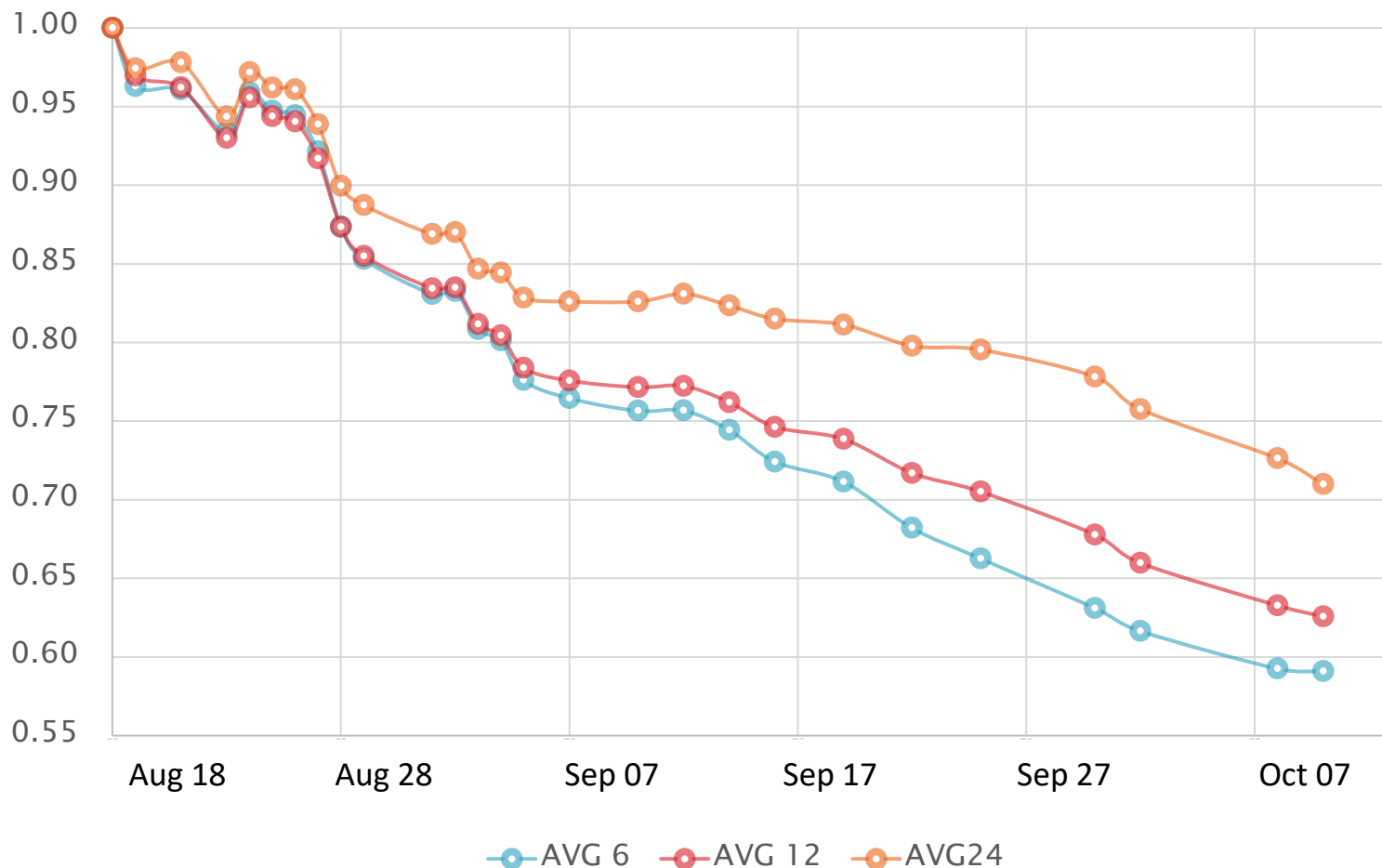
The PVP accumulated yield is significantly more affected by the dust accumulation rates than the inclination angle.

Installation Slope	Normalized Yield – Clean	Normalized Yield – Unclean
24 deg wash	1.12	
24 deg broom	1.00	1.00
12 deg	0.97	0.94
6 deg	0.96	0.85

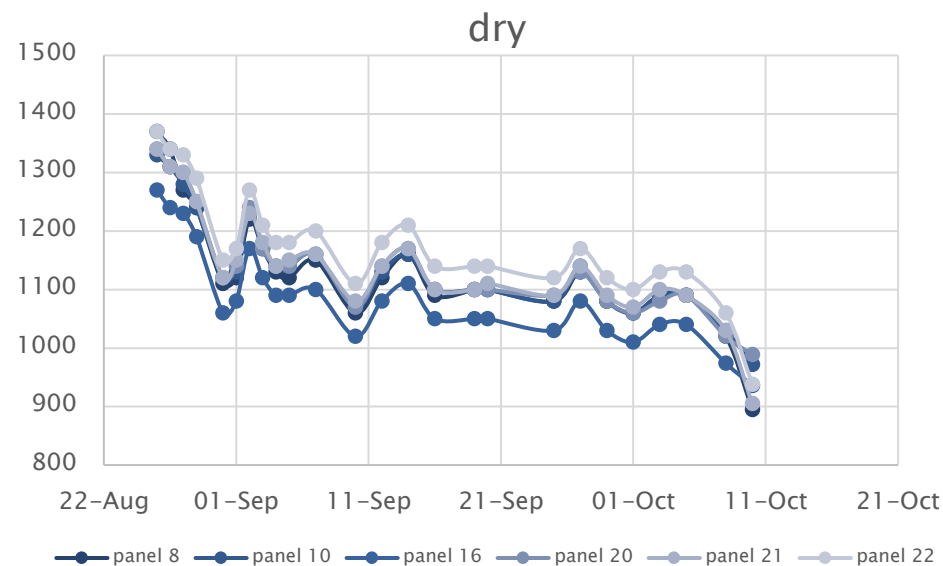
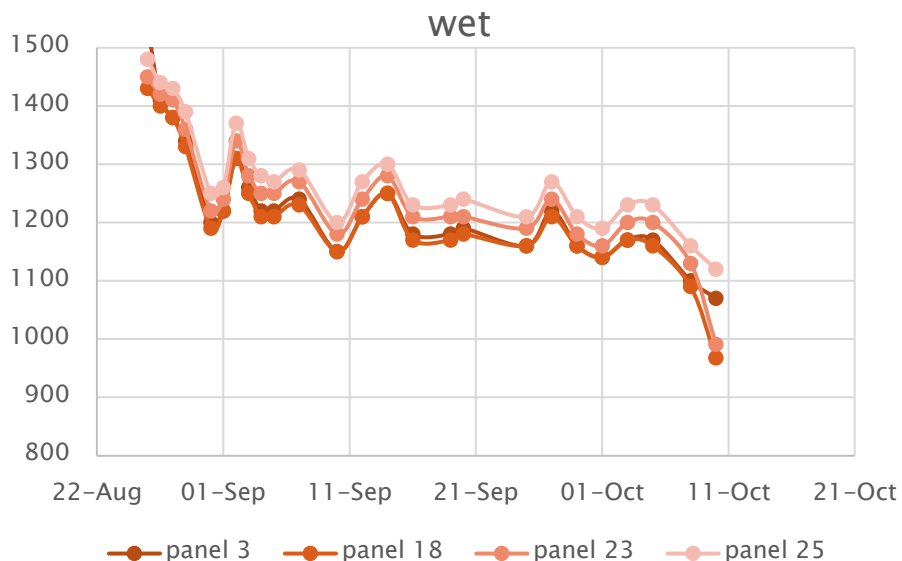
# PVP yields of different inclinations



# Average yield change influenced by PVP inclination

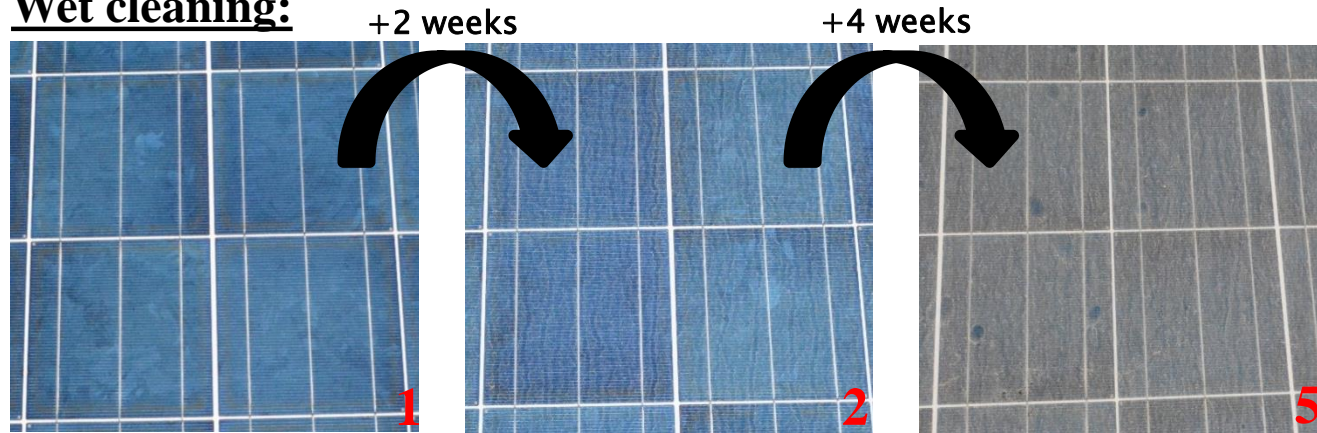


# Wet cleaning vs. Dry cleaning



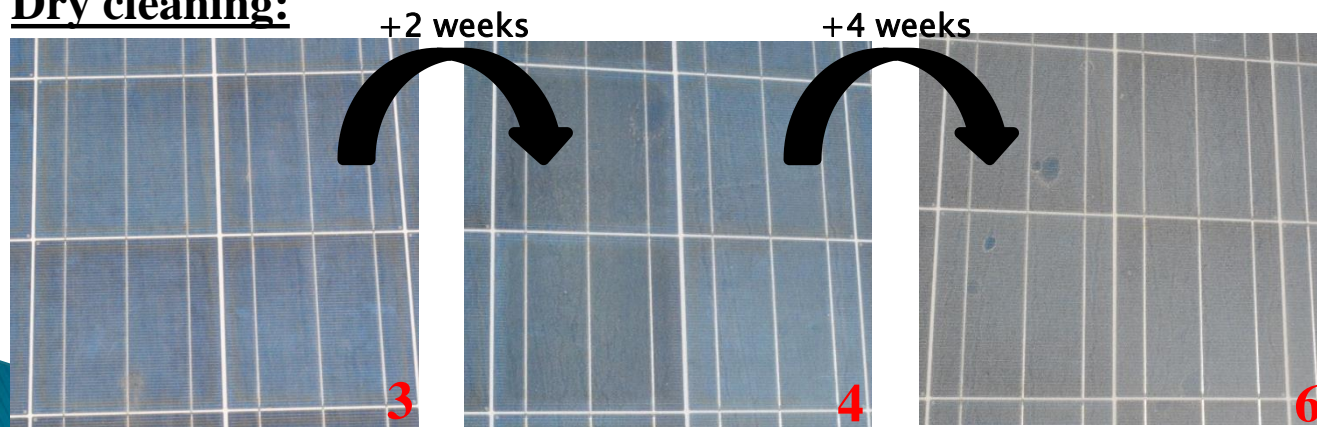
# Cleaning Levels

## Wet cleaning:

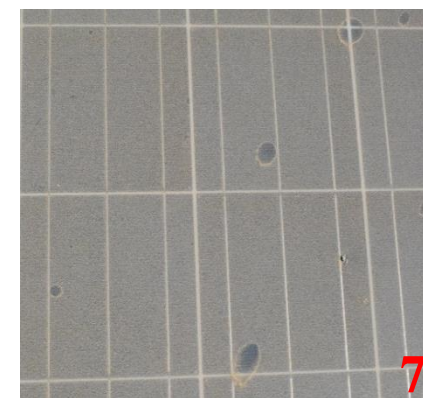


Cleaning Level	Picture No.
Wash	1
Wash after 2 weeks	2
Broom	3
Broom after 2 weeks	4
Wash after 6 weeks	5
Broom after 6 weeks	6
unclean	7

## Dry cleaning:



## Unclean:



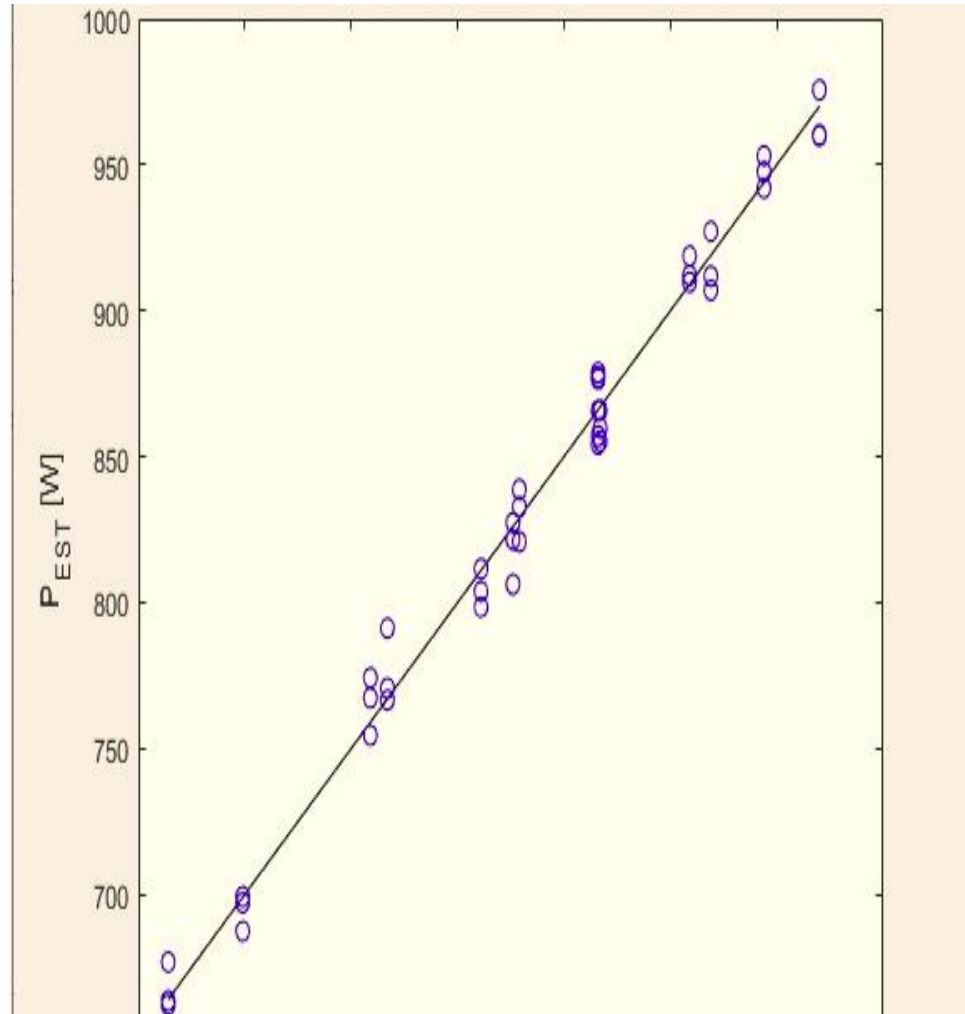
# Average Normalized Yield

Cleaning Level	Description	Normalized Production (to wet cleaning)
1	Wash	$1 \pm 0.01$
2	Wash after 2 weeks	$0.95 \pm 0.01$
3	Broom	$0.9 \pm 0.01$
4	Broom after 2 weeks	$0.88 \pm 0.02$
5	Wash after 6 weeks	$0.86 \pm 0.01$
6	Broom after 6 weeks	$0.79 \pm 0.02$
7	unclean	$0.66 \pm 0.03$

The yield lose rate is similar for both cleaning methods  
About 14% yield decrease after 6 weeks



# Image processing vs. panels yield



Max.  
Yield

30%

Min.  
Yield

# Predicting the PVP yield



# Optional Interested parties

- Homeowners: when to clean and personal optimal inclination
- Commercial PV panel interface: useful data for users
- Commercial rooftop renters for PVP installation: cost-effective cleaning
- Commercial solar energy producers: addition of a light sensor into the PVP
- Solar panel producers: creating an upgraded cleaning robot with image processing abilities detecting cleaning necessity

# Summary

- Is the recommendation for PVP's inclination for homeowners the optimal choice?
- As a homeowner, you could match your cleaning persistency to your installation angle choice for maximum yield.
- Wet cleaning once every 2 weeks will increase PVP yield by 10% compared to dry cleaning.
- Image processing has the potential to become a tool for predicting the panel's yield

# Further study

- Test out yield decay for panels with an inclination angle that is higher than  $26^\circ$ .
- Recommendations for productivity loss vs. cleaning cost
- Improve image processing by using photography techniques that reduces weather condition effects.

# Thank You

