

# Degradation of Solar Cells

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May 17th, 2018

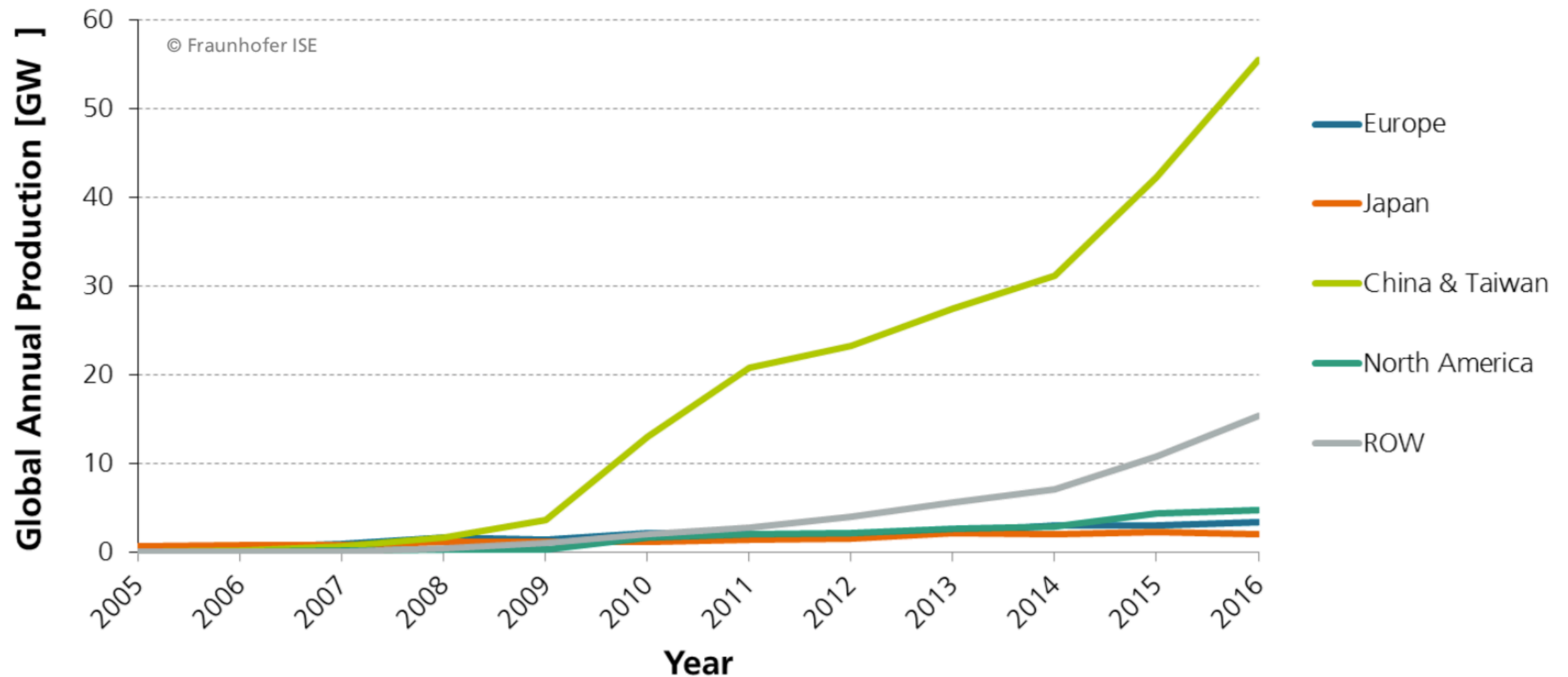
Physics of Semiconductor 2018  
Xi'an Jiaotong University

# Outline

- Introduction
- Three ways solar panels degrade
- Future directions on solar panels studies
- Outlook

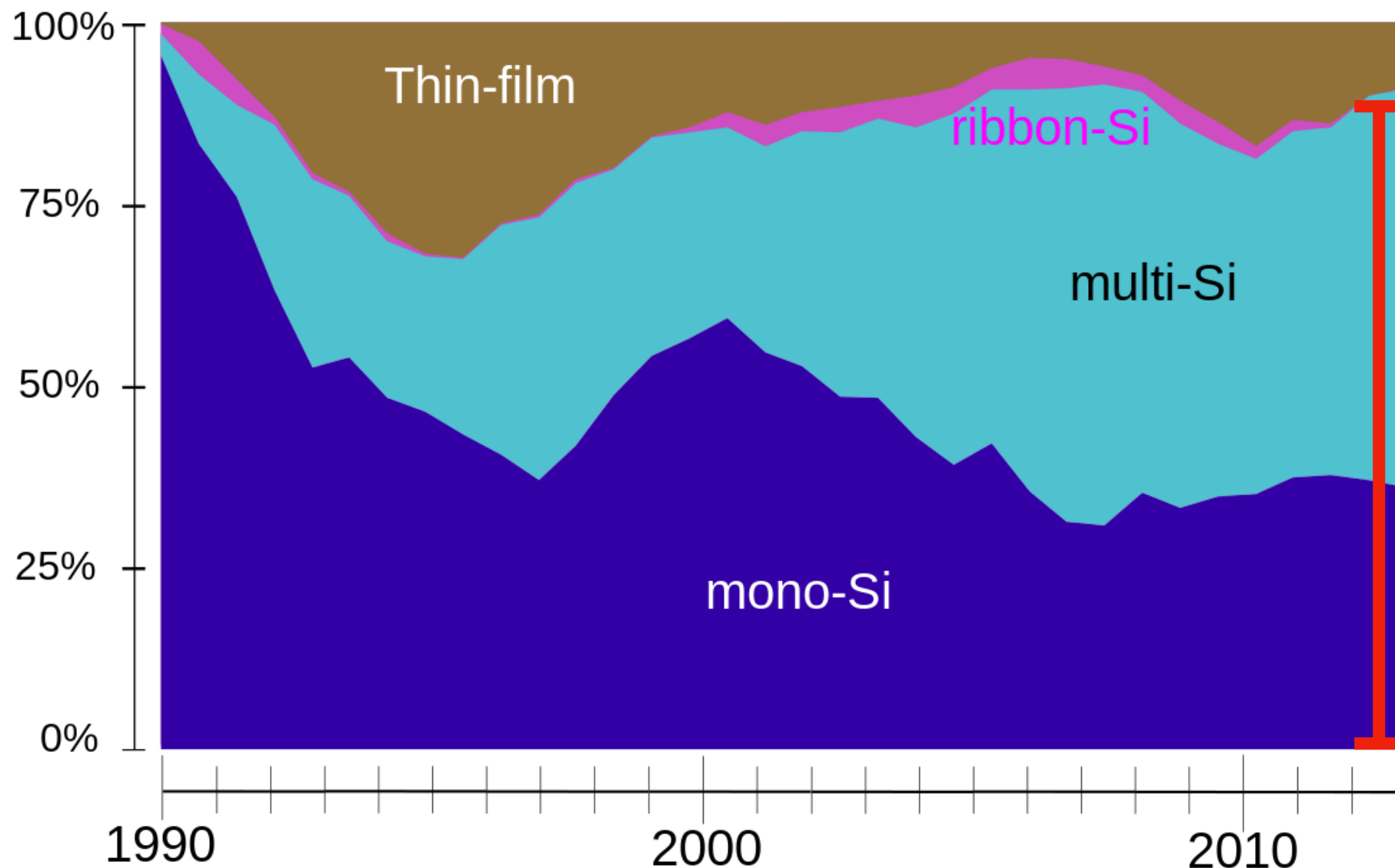
# Introduction

## Global Annual Energy Production from Solar Energy



# Introduction

Global Market Share by PV Technology  
from 1990 to 2013



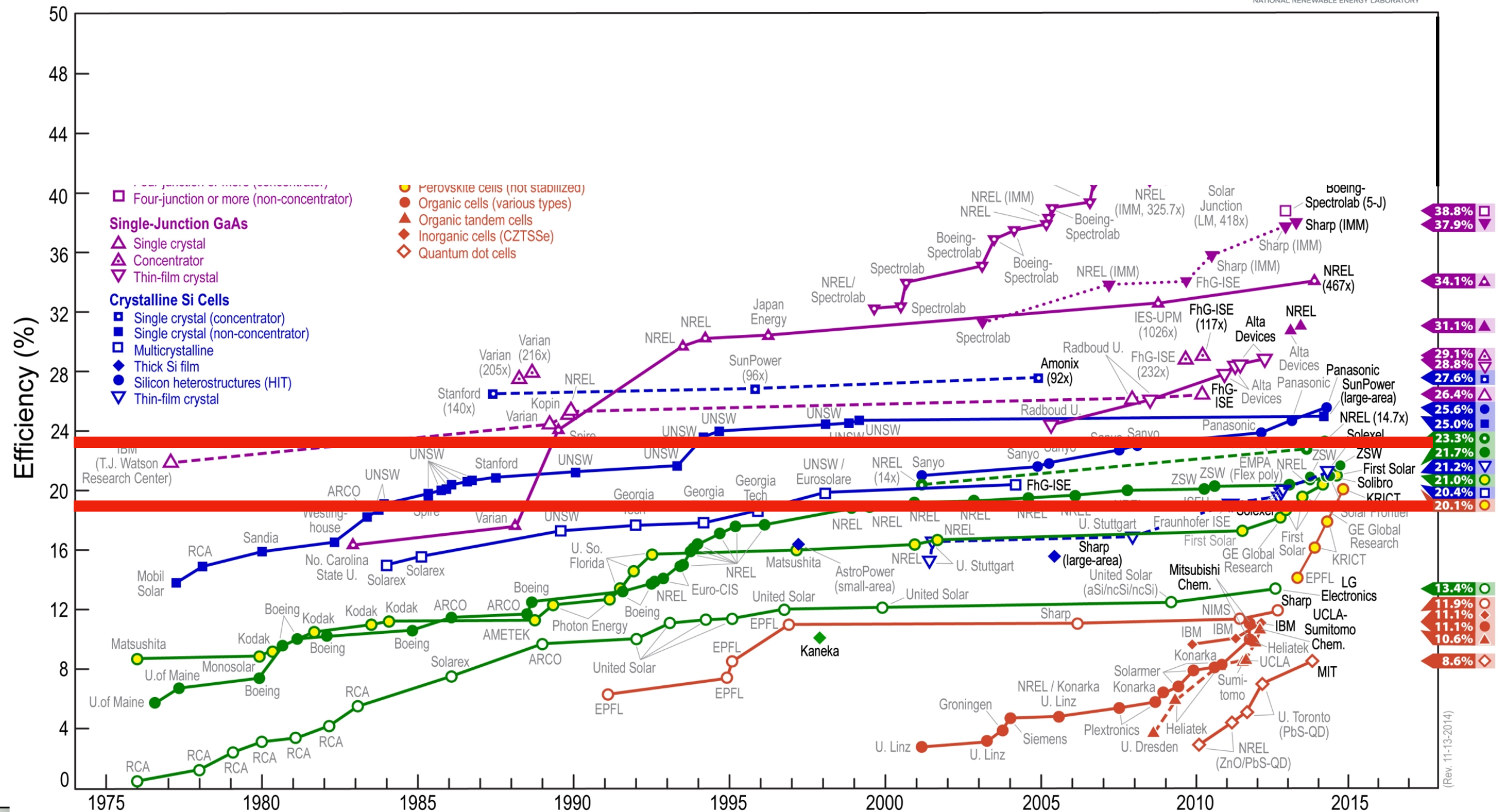
Majority of solar panels are crystalline silicon cells

	%
Thin film	4.9
Multi-Si	57.5
Mono-Si	20.2

# Introduction



## Best Research-Cell Efficiencies



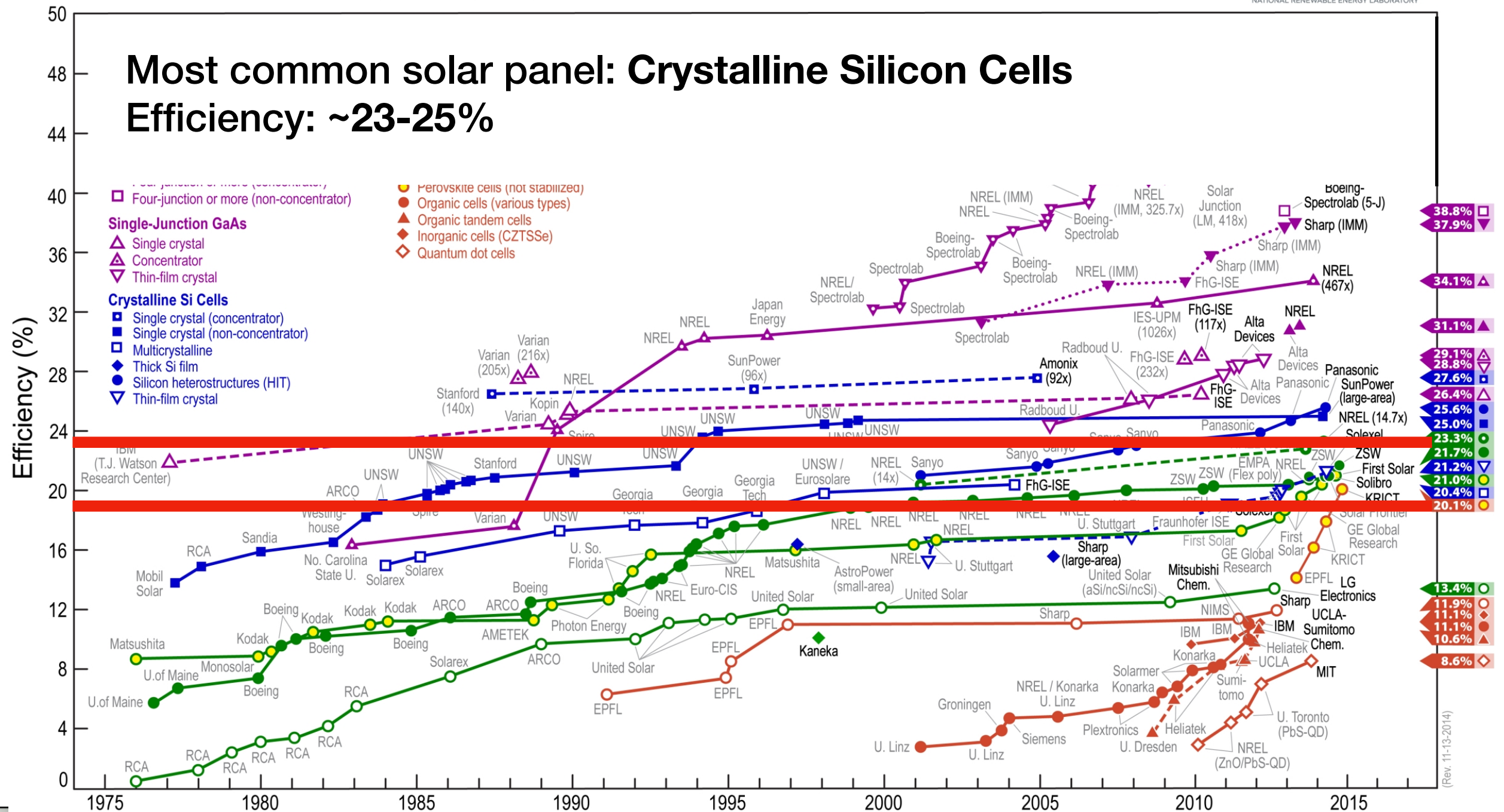
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# Introduction



## Best Research-Cell Efficiencies



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# Introduction

- Solar energy is becoming **major world's energy source**
- Most solar panels are **crystalline silicon cells**
- Efficiency: **~23-25%**
- There are **limited number** of solar panel degradation studies
  - There are some initial studies
  - Better maintenance of solar panels
  - Prediction method

# Three ways solar panels degrade

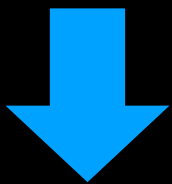


# Three ways solar panels degrade

## *Overview*

### Soiling

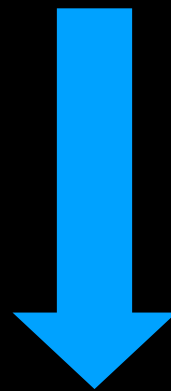
- Snow
- Dirt
- Dust
- Leaves
- Pollen
- Bird droppings



**Current drop**  
**Voltage drop**  
**Hot spot**

### Heating

- Open and close circuit during operation
- Heat dissipation



**Cell stress that**  
**cause defects in**  
**the material**

### Mechanical failure

- Physical damages
- Solar cell encapsulation



**Broken frame**  
**that cause cell**  
**degradation**

# Three ways solar panels degrade

## *Soiling*



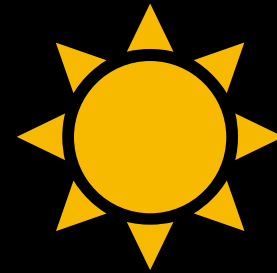
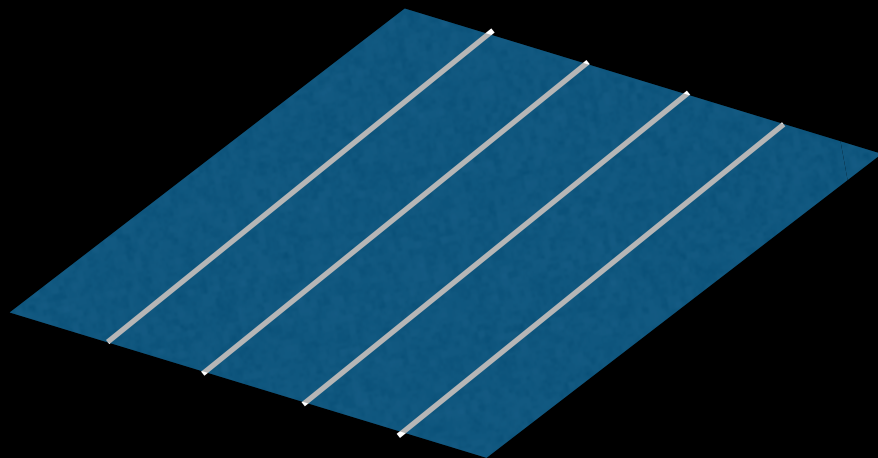
Cloud

Air pollution

Fog

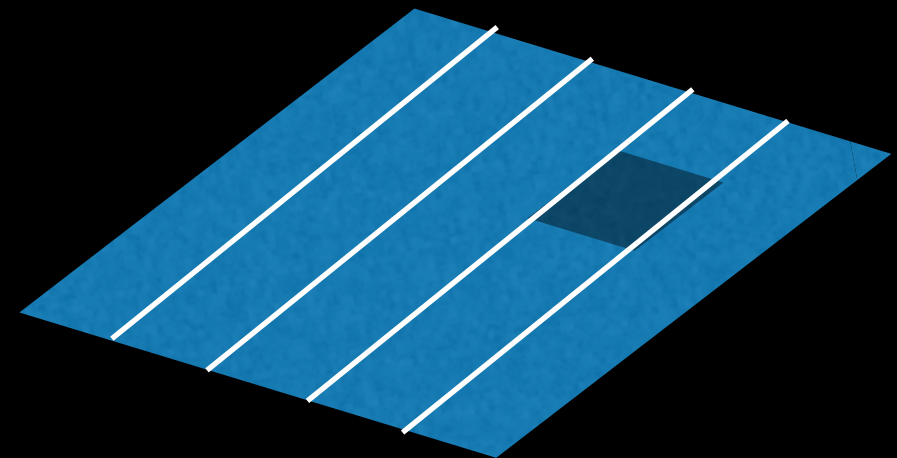
Dust

~ 20% loss in efficiency



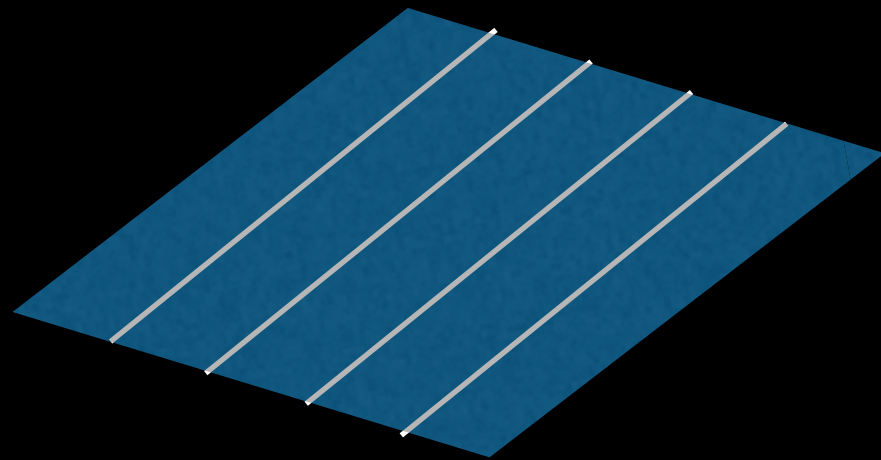
Partial shadow

Bird droppings

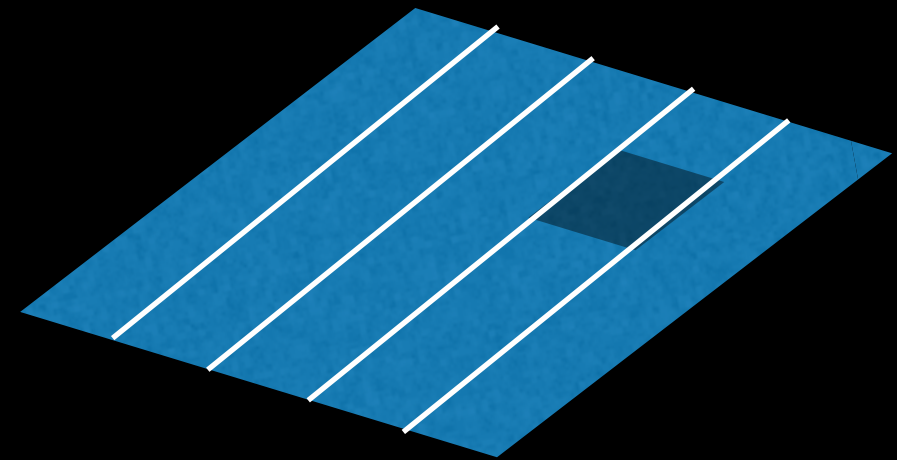
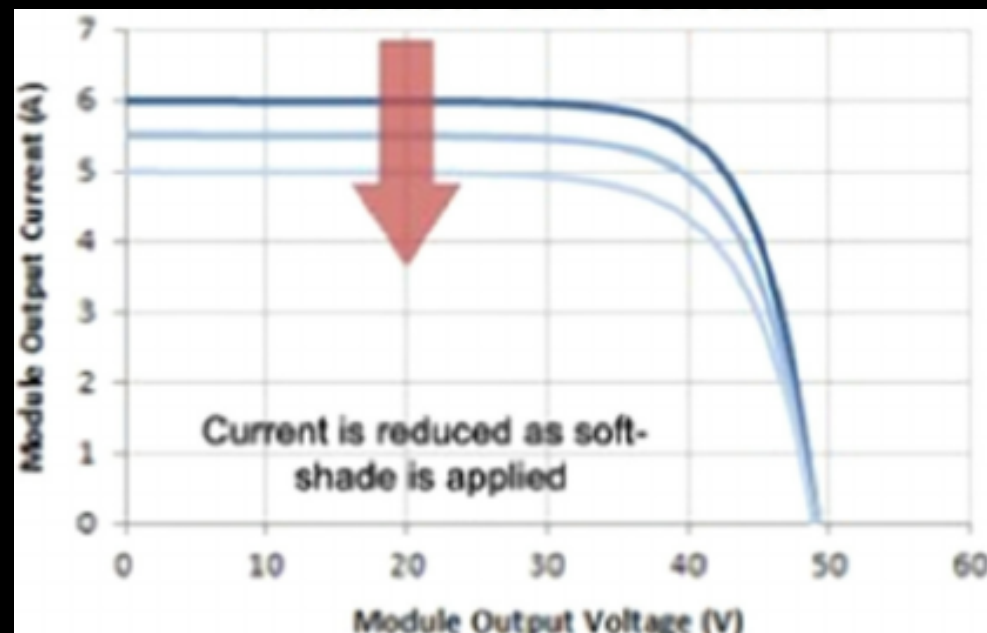


# Three ways solar panels degrade

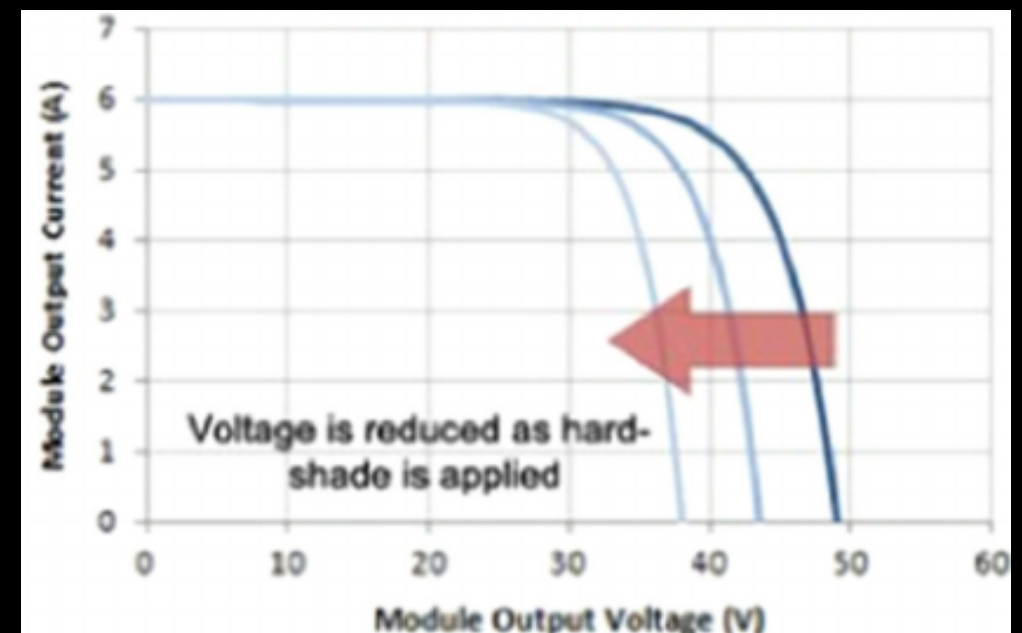
## *Soiling*



**Soft-shade on the module**



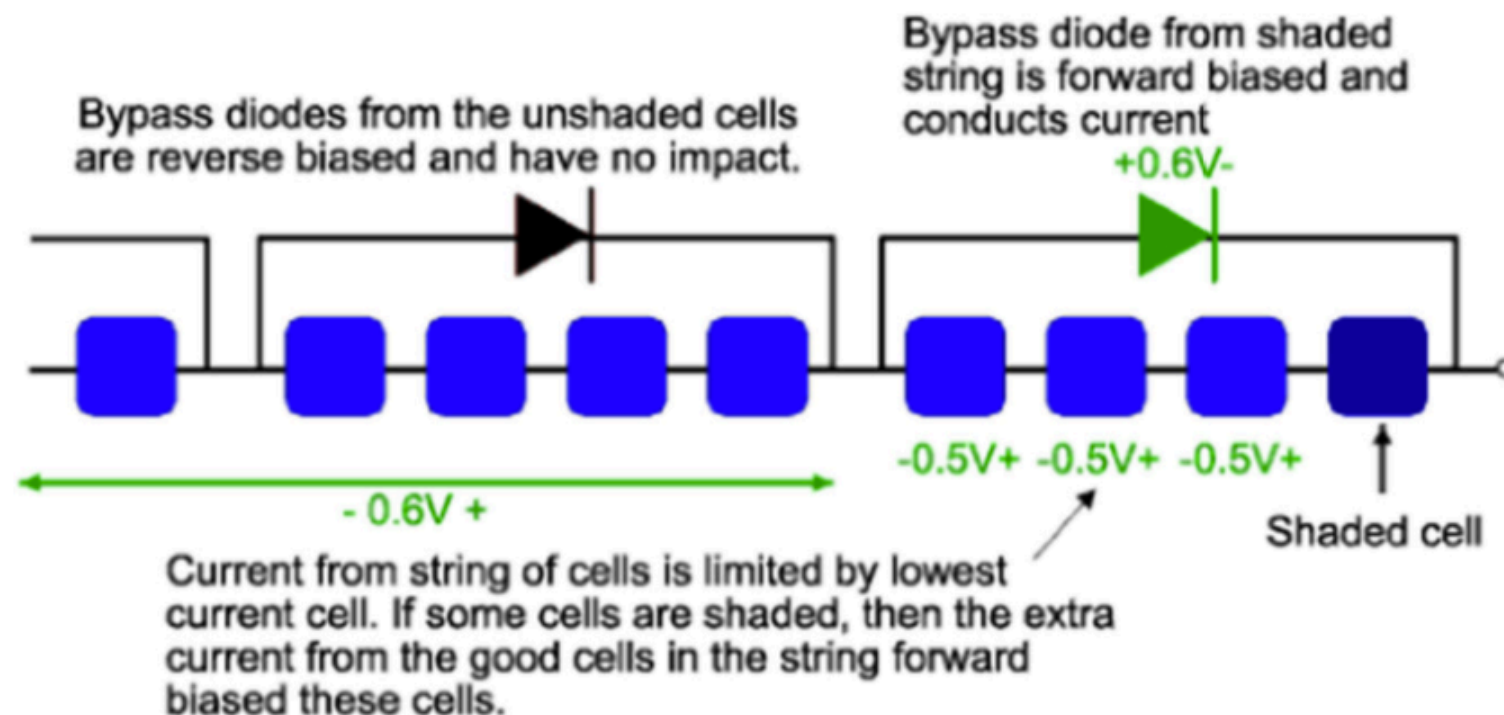
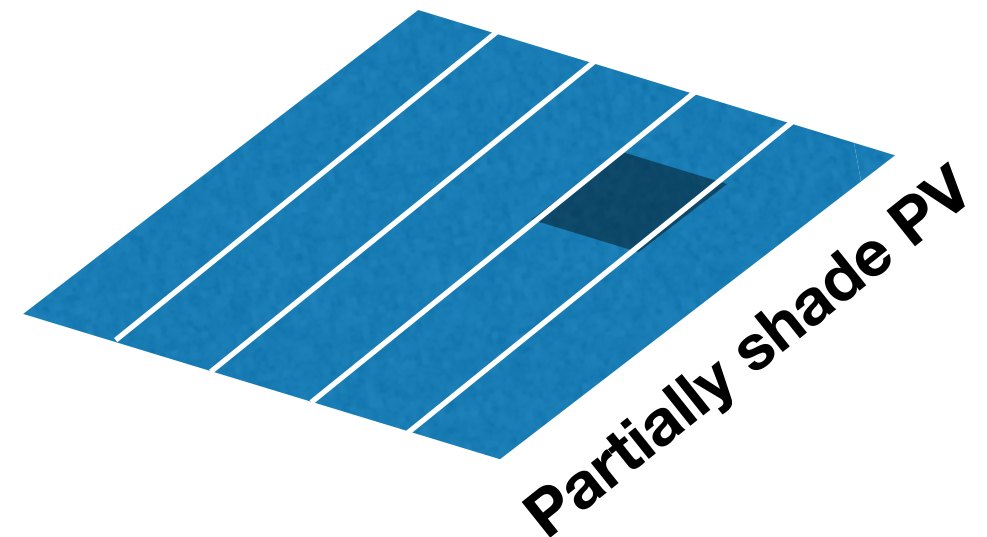
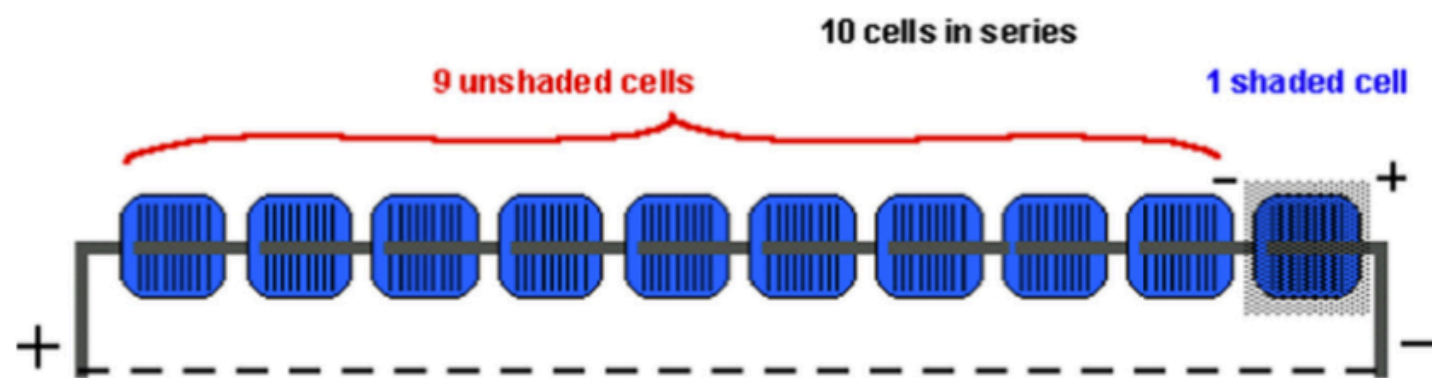
**Partially hard-shade on the module**



# Three ways solar panels degrade

## Soiling

-> The shaded cell could become a **hot spot**

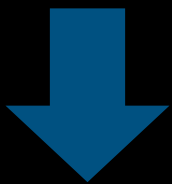


# Three ways solar panels degrade

## *Overview*

### Soiling

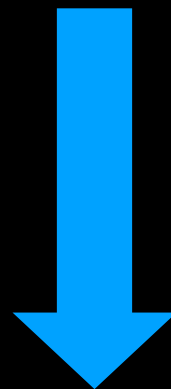
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**Current drop**  
**Voltage drop**  
**Hot spot**

### Heating

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- Heat dissipation



**Cell stress that**  
**cause defects in**  
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### Mechanical failure

- Physical damages
- Solar cell encapsulation

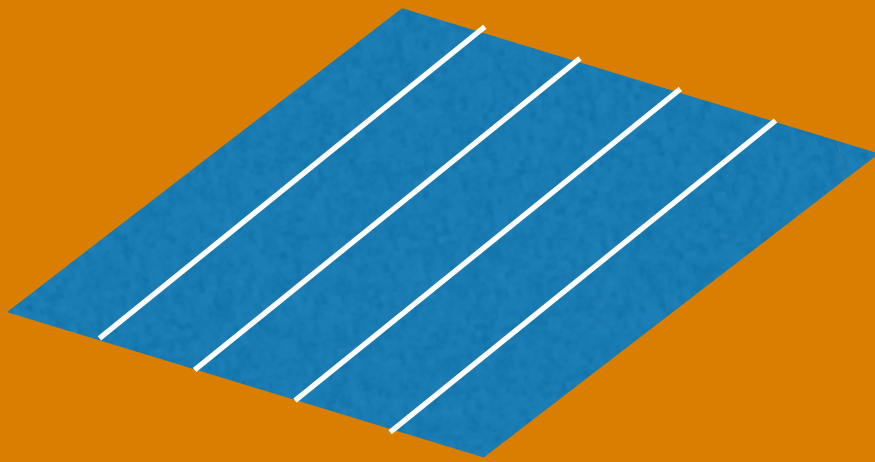


**Broken frame**  
**that cause cell**  
**degradation**

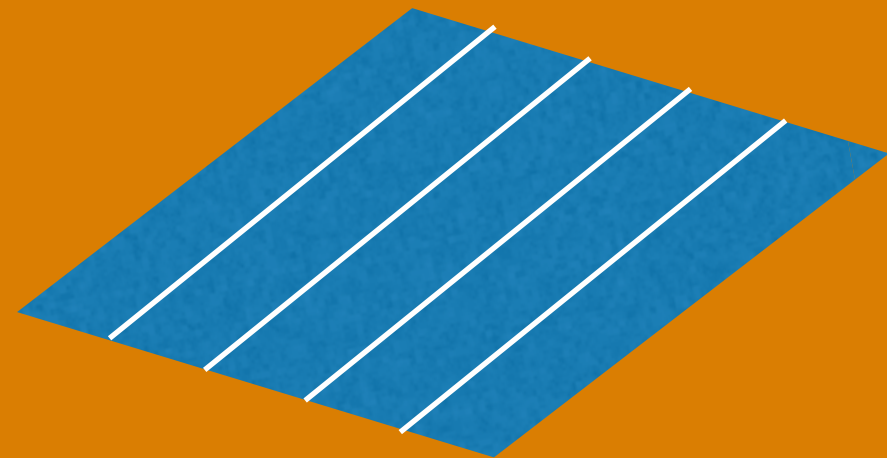
# Three ways solar panels degrade

## *Heating*

**Question!**



**Closed-circuit PV module**



**Open-circuit PV module**

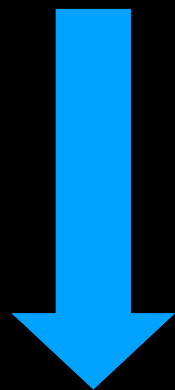
**Which one will degrade faster?**



# Three ways solar panels degrade

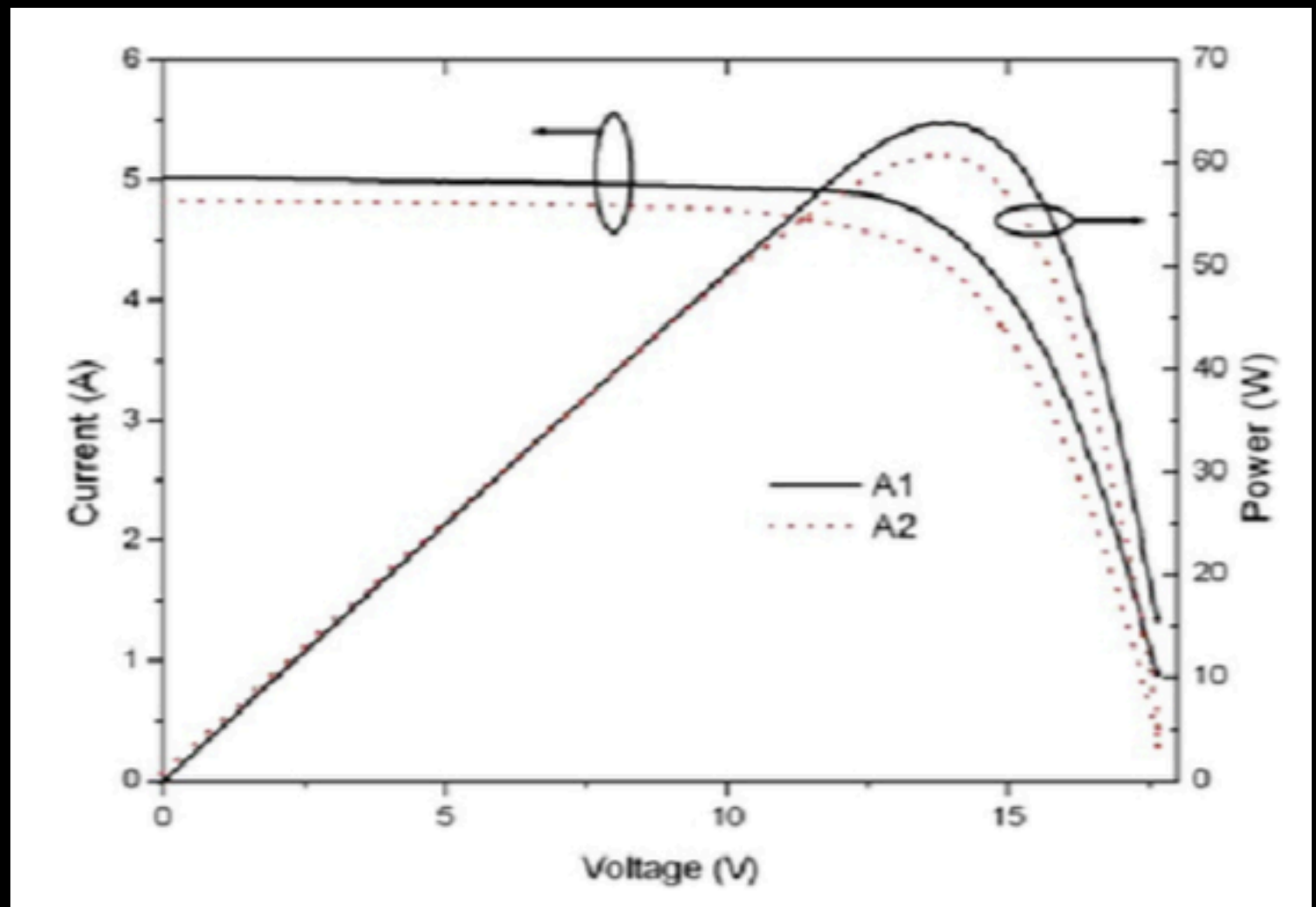
## *Heating*

- Open and close circuit during operation
- Heat dissipation



**Cell stress that  
cause defects in  
the material**

I-V and P-V curve of solar panel that experience lower and higher heat in 330 days

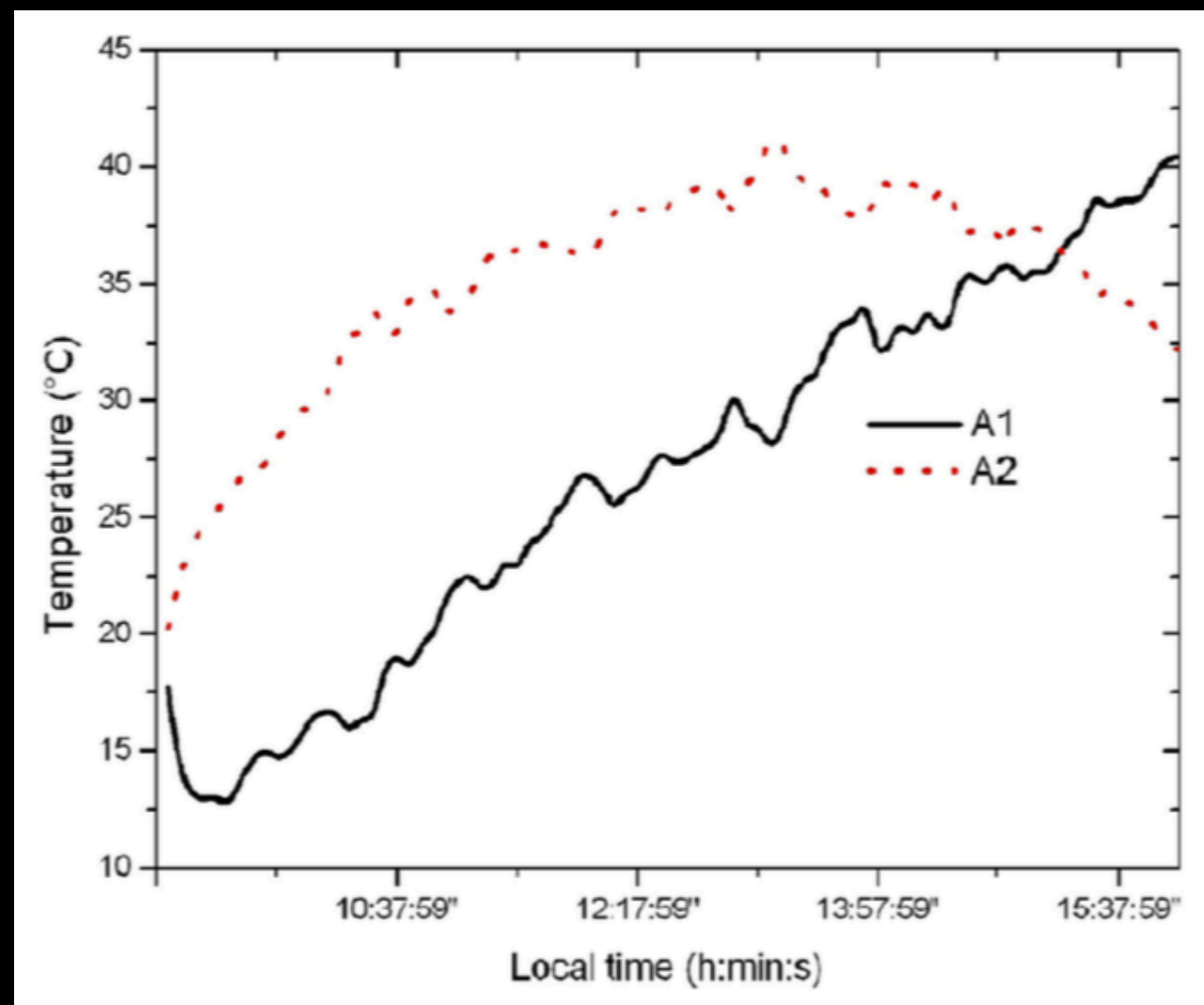


(Boussaid, Belghachi, Agroui, Abdelaoui, & Otmani, 2016)

# Three ways solar panels degrade

## *Heating*

Changes in the temperature of modules for a day example (Nov 20th, 2015)

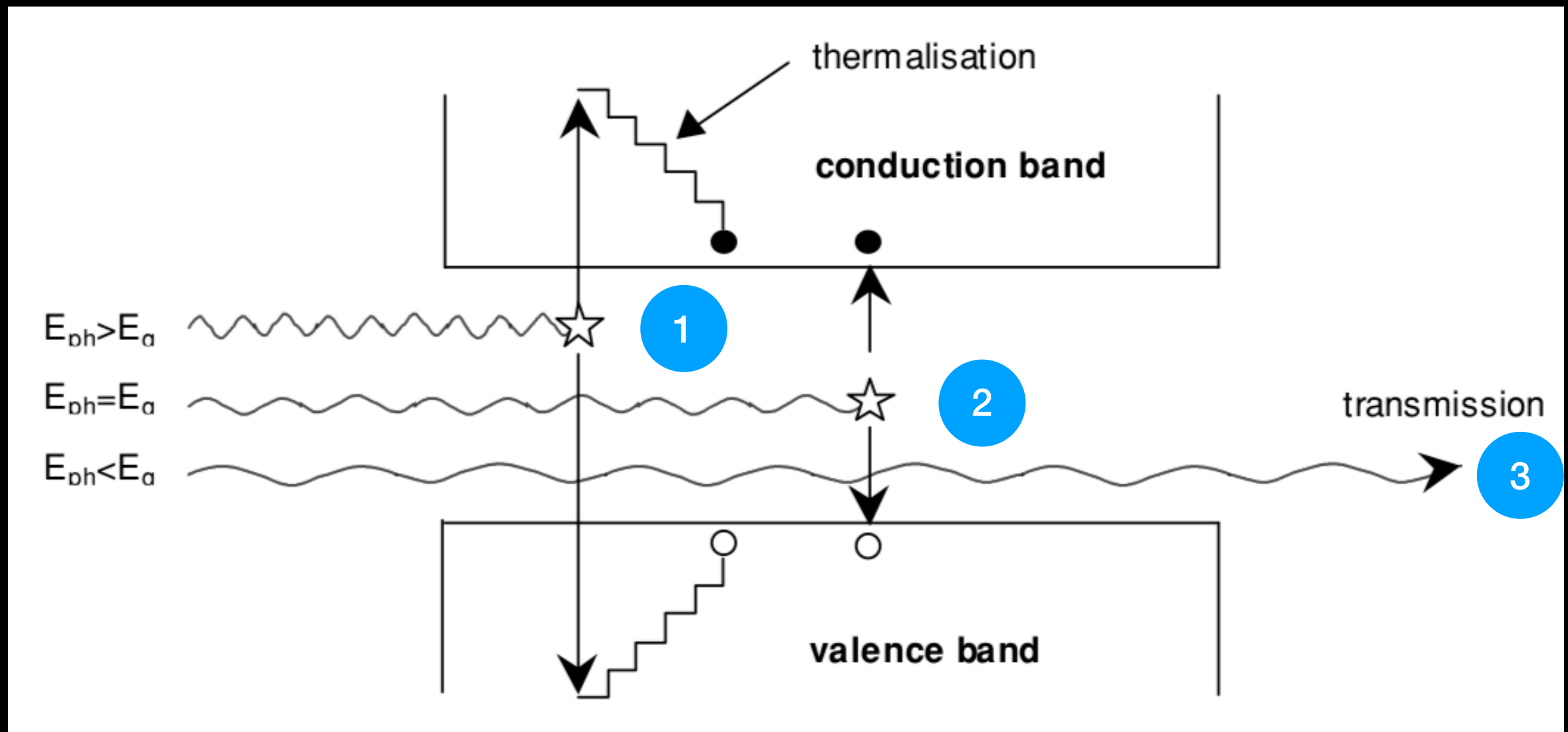


(Boussaid, Belghachi, Agroui, Abdelaoui, & Otmani, 2016)

# Three ways solar panels degrade

## *Heating*

Inter-band transition of electrons in a semiconductor



(Boussaid, Belghachi, Agroui, Abdelaoui, & Otmani, 2016)

# Three ways solar panels degrade

## *Overview*

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- Bird droppings



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### Heating

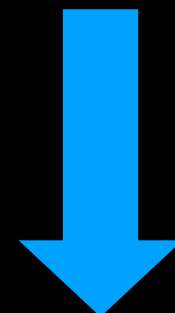
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# Three ways solar panels degrade

## *Mechanical failure*

- Climatic stress:
  - salt -> metal corrosion
  - sand -> glass abrasion
  - hail -> impact
  - snow -> high load (weight)
- Polymers within the panel could be easily damaged by UV irradiation.

# Future directions on solar panels studies



# Future directions

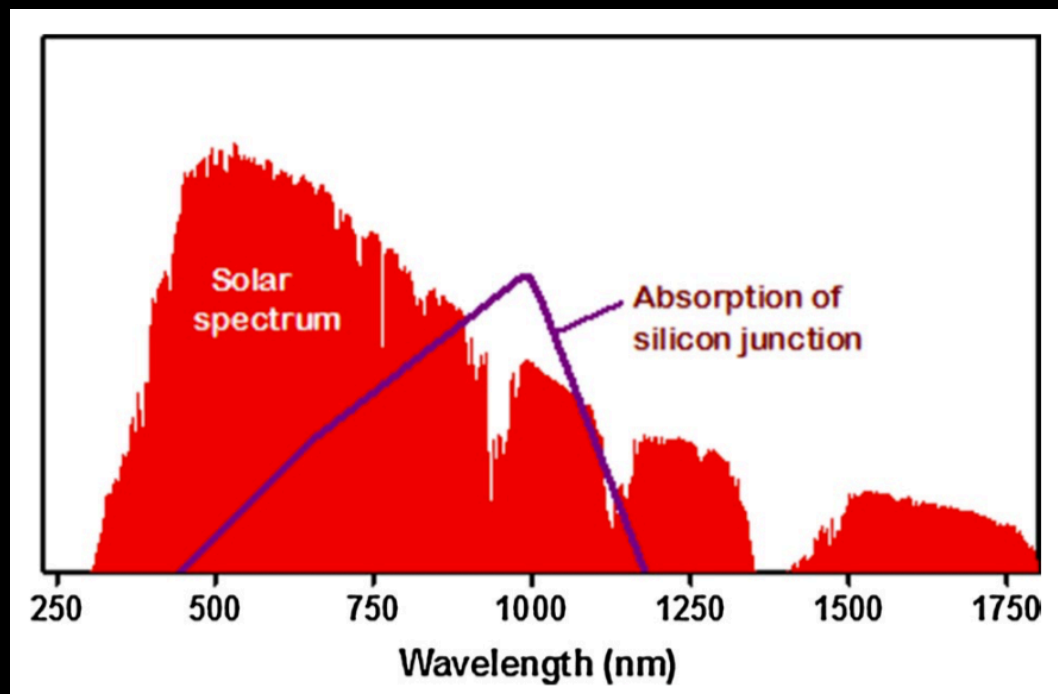
- Develop reliable solar panel lifetime prediction methods
- Study on the cause and prevention of PV degradation
  - For newly manufactured panels
  - For existing panels
- Follow up and long-term studies in different region are needed.

# Outlook

# Outlook

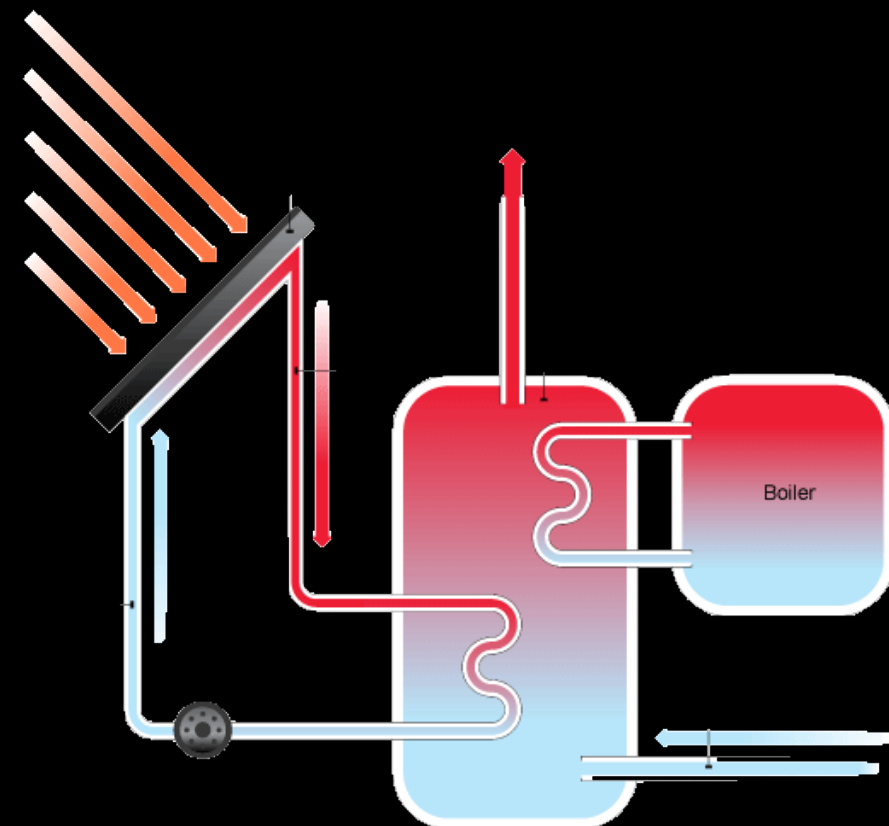
## Reducing the heat

**Solar spectrum  
and Silicon absorption wavelength**



*(Han et al., 2018)*

**Use the wasted solar energy in daytime to  
cool down the system or produce warm water.**



# Outlook

## Cleaning the panel

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### Manual Cleaning

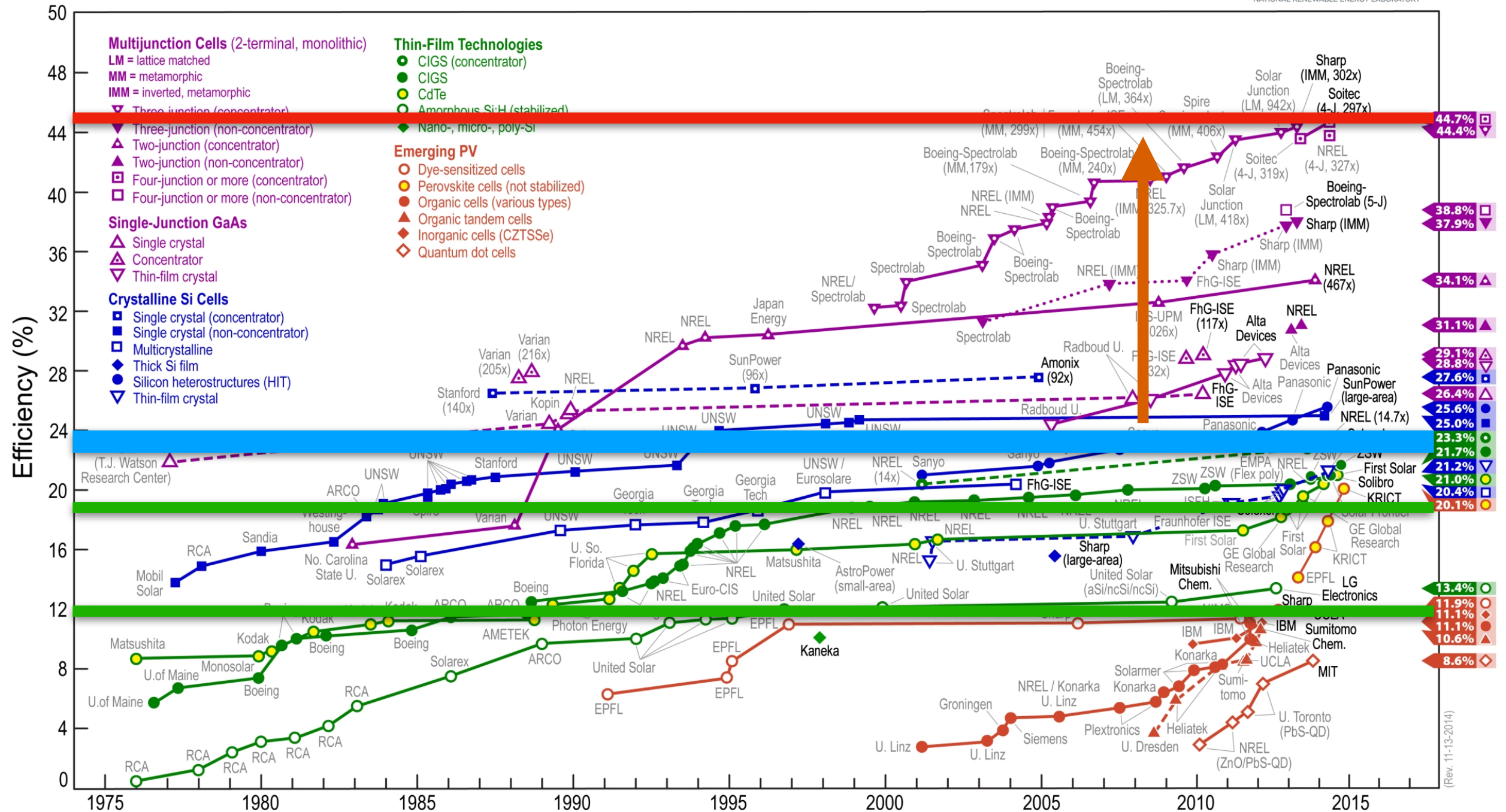
- Need workers
- May scratch the modules

### Mobile Cleaning

- Moving machine with water tank
  - Sprinkler system  
(use daily - weekly)
-

# Conclusion

## Best Research-Cell Efficiencies



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# Supplementary Resources



**Figure 2: The duck curve shows steep ramping needs and overgeneration risk**

