1. **Types of defect frequently occur in solar panels -> why having those deffects?**

Faults can appear in manufacturing, transportation, installation and operation.

* In the first group, it is described the common failures to all PV modules divided in the following failure modes: delamination, back sheet adhesion loss, junction box failure and frame breakage.
* The second group includes the following failures in silicon wafer-based PV modules: EVA discoloration, cell cracks, snail tracks, burn marks, Potential Induced Degradation (PID), disconnected cell and string interconnect ribbons, defect bypass diode.
* The thin-film failures described in the third group are: micro arcs at glued connectors and shunt hot spots.
* And finally, the fourth group describes the following failures found in CdTe thin-film modules: front glass breakage and back contact degradation. In reference different aging mechanisms that take place in PV modules and their cause-effect links are presented, as discoloration, delamination, bubbles, coating degradation, corrosion, crack in the cells, ribbon and solder bonds degradation and broken interconnect, dust and soiling, PID, junction box and bypass diodes effects, localized heating phenomena and detachment of the frame. Ideally, PV cells with defects are identified and replaced during the manufacturing process, using methods such as ultrasound, infrared thermography or Electroluminescence (EL) imaging [35]. However, new defects may appear during transportation, installation and operation due to shadows, cracks, interconnection of modules, degradation or other problems [36]. These defective cells create inequalities in current density that can lead to huge currents across small areas, causing very high temperatures (hot spots) responsible for module degradation or even irreparable damage.

1. **How to identify those defects: based on thermal images, thermal sensors?**

* Visual inspection: This involves physically examining the solar panel for signs of damage, discoloration, or other visible defects.

**For example:** typical failures found during visual inspections according to IEC 61215 [37] are bubbles, delamination, yellowing and browning in the front of the module, broken cells or discolored anti reflection, burned or oxidized cells metallization, failures in the frame, delamination, bubbles, scratches or burn in the back of the module, loose, oxidation or corrosion in the junction box and detachment or exposed electrical parts in wires or connectors

**Pros:** Simple to apply, quick, cheap

**Cons:** cannot detect all failures

* Electroluminescence testing: This involves capturing images of the solar panel in complete darkness while it is under an electrical charge to detect any defects.

**Meaning:** electrical performance of the system, and its main parameters, but it cannot be performed in common operation. In order to be able to compare results, since it is not always possible to measure the curve in the Standard Test Conditions (STC), it is necessary to apply a translation procedure, which can be used in a certain range from the measured conditions

**Pros:** relevant information about the module failures, revealing degradation, mismatched modules, cracked cells, improper resistance, shadings or bypass diodes malfunction.

**Cons:** although it allows the identification of abnormal underperformance situations, it gives vague information to recognize the exact reason and the location of the faulty module or cell.

* thermographic inspection IRT: This method uses thermal imaging cameras to detect any hotspots or cold spots on the solar panel that may indicate defects. Ex: cell hotspot, overheated bypass circuit, junction box, connection or whole module. -> use drone -> automation
* Performance testing: This method measures the output of the solar panel over time and compares it to the expected output to identify any discrepancies that may indicate a defect.

1. **How to fix those defects?**

* Cracks or scratches: These can occur due to physical damage or thermal stresses. The affected area can be cleaned and sealed using a specialized sealant designed for solar panels.
* Hot spots: These can occur when there is a mismatch between solar cells or due to shading. Hot spots can be fixed by replacing the affected solar cells or by reconfiguring the panel to avoid shading.
* PID (potential-induced degradation): PID can occur when there is a voltage potential between the solar panel's conductive components and the ground. The solution for PID is to use a specialized PID recovery device that can restore the panel's performance.
* Discoloration or yellowing: These can occur due to exposure to UV light or other environmental factors. The affected panel or section of the panel can be replaced.
* Delamination: This occurs when the layers of a solar panel start to separate. The affected section can be removed and replaced with a new section.