1. Problems
- Module degradation rates are strongly correlated to the number of cracked cells.
- IEC 61215 is lenient regarding cracked cells.
- Few modules are tested for cracks in the field by electroluminescence (EL); just in factory.
- No clear agreement on how to interpret EL images or how to react to cracked cells.
- Without wider testing and consequences, module manufacturers have little incentive to improve designs and may not even be aware that they should.
- There is immense difference in the crack resistance of different module designs, but most module buyers are clueless.

2. How enhance & interpret EL images?
- Blotches in repeating pattern - Si growth or cell processing contamination. Not cracks.
- Repeating pattern - poor screen printing. Not cracks.
- Curved and non-continuous lines on mono cells - Cell processing contamination. Not cracks. Many mono cells are at 45°.
- "X" cracks: Rear side point impact, likely post shipping, sometimes from cable connectors swinging against back.
- Line of "X" cracks: Rear side dragging impact, possibly from dragging a corner of another module across backsheet when unpacking pallet.
- Dense dendritic crack pattern. Likely cracked at high load level with high release of energy. Shunting makes image dark. Worse low-light performance.
- "Crow's feet" V cracks at wire tips: poor soldering.
- Dark finger regions consistently going up to busbars: Likely cracks in fingers but not in Si; poor metallization and/or tabbing process/design.
- Dark regions around 1 or more busbars: poor soldering or cracked wire.
- Closed cracks – no power loss. Yet.
- Open cracks – possible power loss and hot spots.

3. How and when test panels?
- Systems: Throughput (modules/hr with 2 workers)
  - Tripod systems 20-60
  - Trailer systems 40-120
  - Drone systems >120
- Pros: Cons
  - Lowest cost  Focus on challenging
  - Easy to transport  More expensive
  - Reproducible conditions  Undesirable to deploy
  - Can do IV and other tests  Difficult to move far
  - Can test during daytime  More expensive
  - Best for difficult access  Focus more
- Improving the degradation rate or service lifetime has huge impact on LCOE (NREL Comparative LCOE calculator).

4. How to respond to EL images?
- Testing after shipping:
  - Why accept any cracks?
  - How much higher $/W to demand replacement from module supplier of panels with any cracks?
- Testing of older systems:
  - Is it acceptable to add a "band-aid" to badly designed or compromised modules?
  - What damage can be ignored
  - What damage requires further testing?
  - What damage requires replacement?
- Testing right after installation:
  - Why accept any cracks?
  - How much higher $/W to demand replacement from installer of panels with any cracks?

5. References