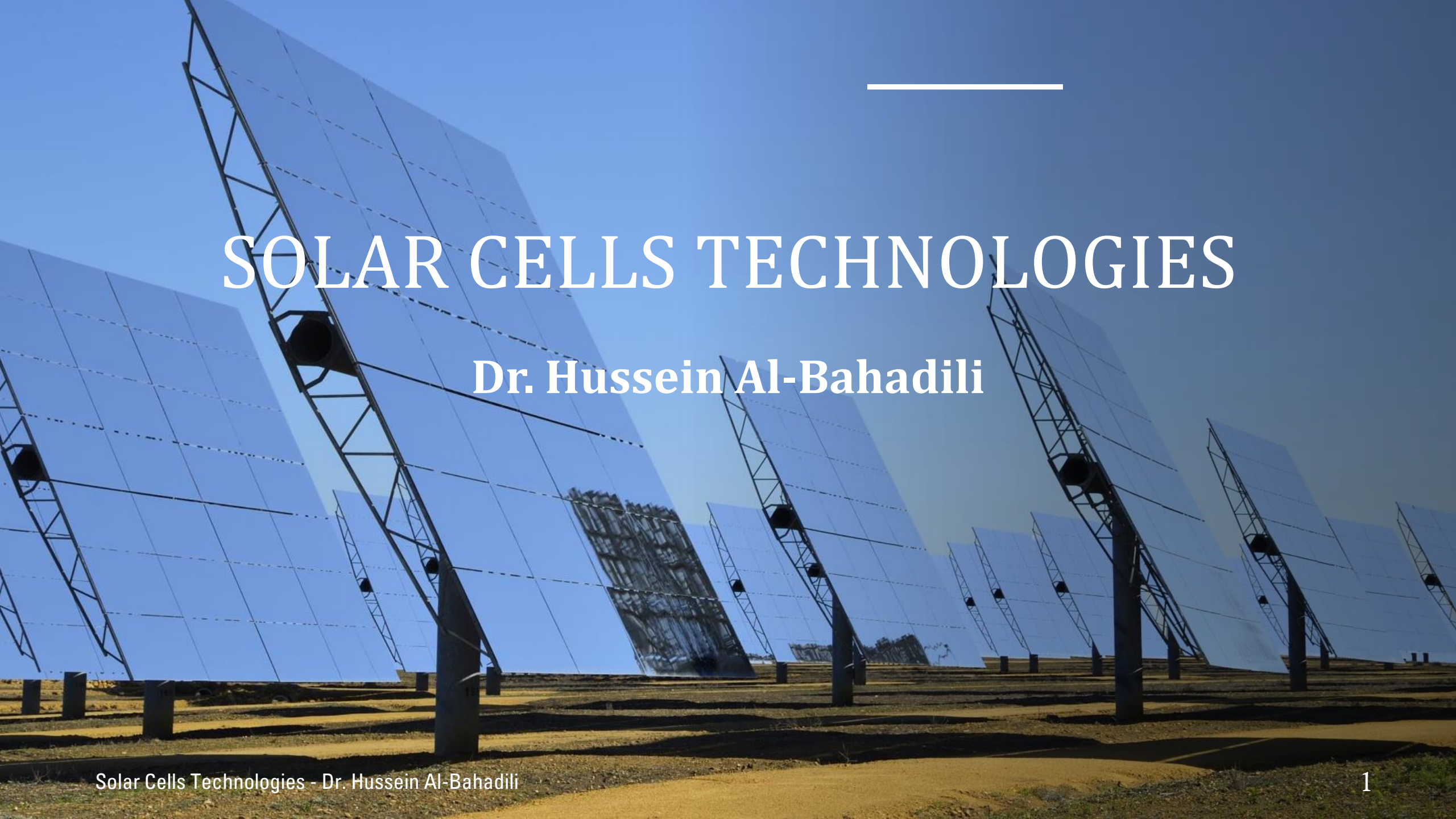

SOLAR CELLS TECHNOLOGIES

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Solar Cells Technologies

- As of 2025, the highest-efficiency solar cell technologies available for commercial use are:
    1. TOPCon (Tunnel Oxide Passivated Contact) Solar Cells
    2. Heterojunction Technology (HJT)
    3. IBC (Interdigitated Back Contact) Solar Cells
    4. Perovskite-Silicon Tandem Cells (Emerging for near-future commercial)

TOPCon (Tunnel Oxide Passivated Contact) Solar Cells

- Efficiency: ~23% to 24.5% (commercial module level)
- Type: Crystalline silicon (n-type)
- Highlights:
  - Higher efficiency than PERC
  - Better low-light performance
  - Excellent temperature coefficient
- Commercial Use: Adopted by major manufacturers like Jinko, JA Solar, and LONGi

- TOPCon is an advanced solar cell technology that uses a thin tunnel oxide layer and a passivated contact structure to reduce electron recombination and increase efficiency.
- Built on high-purity n-type silicon wafers, TOPCon cells offer improved performance over traditional PERC cells, especially under high temperatures and low-light conditions.
- It is now widely adopted in utility-scale and floating PV projects due to its excellent balance of efficiency, reliability, and scalability.

Heterojunction Technology (HJT)

- Efficiency: ~23.5% to 25%
- Type: Hybrid of crystalline silicon and amorphous silicon
- Highlights:
  - Very high efficiency and low degradation
  - Excellent bifacial performance
  - Lower temperature coefficient
- Commercial Use: Panasonic, REC Group, and others have mature products; new players are scaling up

- Heterojunction solar cells combine crystalline silicon wafers with thin layers of amorphous silicon to form a high-efficiency structure with superior passivation.
- This hybrid architecture enables low degradation, excellent temperature performance, and high bifaciality, making HJT ideal for premium applications and locations with varying irradiance.
- It is increasingly used in utility and floating PV systems aiming for maximum yield and long-term stability.

IBC (Interdigitated Back Contact) Solar Cells

- Efficiency: ~23% to 24.5%
- Type: High-end monocrystalline silicon
- Highlights:
  - All electrical contacts at the back → higher front-side efficiency
  - Sleek, all-black look (often used in residential premium markets)
- Commercial Use: SunPower (Maxeon series) is the main producer

- IBC solar cells relocate all electrical contacts to the rear of the solar cell, eliminating front-side shading and enabling higher light absorption.
- This design maximizes power output while offering a sleek, uniform appearance.
- Although IBC cells are more complex to manufacture, they deliver very high efficiencies and are mainly used in premium residential and commercial applications where space and aesthetics matter.

Perovskite-Silicon Tandem Cells (Future Commercial)

- Efficiency: Lab record > 33%, early comm. ~26-28%
- Highlights:
  - Combines perovskite top cell with a silicon bottom cell
  - Highest theoretical and lab-tested efficiencies
- Commercial Status: Pilot-scale production started; full commercial deployment expected by 2026–2027

- Perovskite-silicon tandem cells stack a perovskite solar cell on top of a traditional silicon cell to harvest a broader range of the solar spectrum.
- This dual-layer design significantly boosts efficiency beyond the limits of silicon alone.
- Although still in the early commercial phase, this technology has demonstrated record-setting efficiencies in laboratories and is expected to play a leading role in next-generation solar power plants.

Summary: Current Best Options for Large-Scale Commercial Use

Technology	Typical Efficiency	Best Use Case	Availability
TOPCon	23–24.5%	Utility-scale & FPV	Widely used
HJT	23.5–25%	Premium + Bifacial	Expanding
IBC	23–24.5%	High-end residential	Available
Perovskite-Si	26–28% (early)	Next-gen commercial	Emerging

Recommendations

- State-of-the-art technology for a utility-scale FPV system would be either:
- TOPCon for high efficiency & cost-effectiveness.
- HJT if aiming for best performance with bifacial gain (especially beneficial over water).