Perovskite Solar Cells: Stability Challenges and Commercial Viability

From 3.8% to 25.8% efficiency – but can they last?

01

Perovskite Solar Cells: Stability Challenges and Commercial Viability

Unlocking the future of renewable energy through next-generation photovoltaics

Presentation Overview

Three key areas to understand PSC commercialization: current state, structural evolution, and stability challenges

01

Current State & Challenges

Efficiency gains vs stability issues in PSCs

02

Structural Evolution

From mesoporous to HTL/ETL-free designs

03

Stability Mechanisms

Degradation causes and environmental factors

04

Commercial Viability

Cost analysis and market readiness

We're about to walk through four key areas that define whether perovskite solar cells can make it to market. We'll start with where we are now, then look at how the technology has evolved, examine why

02

Stability Issues & Degradation Mechanism

Key challenges limiting commercial viability of perovskite solar cells

Key Challenges for Commercialization

The main obstacles preventing commercial viability of perovskite solar cells

- Moisture breaks down organic components in perovskite materials, causing structural degradation that reduces device performance and lifespan.
- Water molecules penetrate through encapsulation layers and react with the perovskite lattice, triggering phase transitions and irreversible loss of photovoltaic
- Heat degrades structure by accelerating ion migration within the perovskite crystal lattice, which disrupts charge transport pathways and leads to
- Elevated temperatures increase defect density in perovskite films, causing rapid degradation of charge carrier mobility and device stability over time. Thermal

These are the five key challenges from our research that prevent commercialization - weak material interactions, efficiency loss, temperature limitations, environmental degradation, and insufficient 1

BEFORE

Early PSCs

2009: 3.8% efficiency
2012: 9.7% efficiency
2015: 15% efficiency

AFTER

Modern PSCs

2018: 20.26% efficiency on rigid substrates
2021: 25.8% efficiency (highest reported)
2022: 22% efficiency with HTL-free design

Key Degradation Factors

Environmental and material factors limit PSC stability

Degradation Factors

Moisture, heat, light, and oxygen cause perovskite deterioration

Moisture ingress

Water breaks down organic components

Thermal stress

High temps degrade perovskite structure

UV exposure

Light causes photo-degradation

Oxygen interaction

Oxidation affects device stability

These six factors represent the core challenges to PSC stability. Moisture, heat, light, and oxygen all contribute to degradation, while intrinsic material instability and interface problems compound.

03

Structural Evolution & Material Advances

How device architecture and materials have evolved to improve PSC performance

PSC vs. Si: Efficiency & Stability Gap

Current perovskite solar cells lag behind commercial silicon technology in stability despite matching efficiency

- Efficiency reaches 25.8%
- Stability lasts <1000h
- Commercial cells >20 years
- Processing requires inert env
- PSCs degrade in months

While PSCs have achieved 25.8% efficiency comparable to commercial Si cells, their stability is orders of magnitude worse. PSCs degrade within months under ambient conditions while Si cells maintain 8

Device Structure

Inverted planar architecture improves stability and P

HTL Materials

CuSCN and NiO_x_ offer better stability than spiro-OM

ETL Advances

SnO2 and ZnO enhance charge extraction

HTL-Free

Eliminates complexity, boosts long-term performance

Critical Stability Metrics

PSCs show high efficiency but struggle with long-term stability

25.8%

Highest reported PCE of PSCs

Recorded in 2021 with inter-layer modification

<1000h

Typical operational stability of PSCs

In ambient conditions without encapsulation

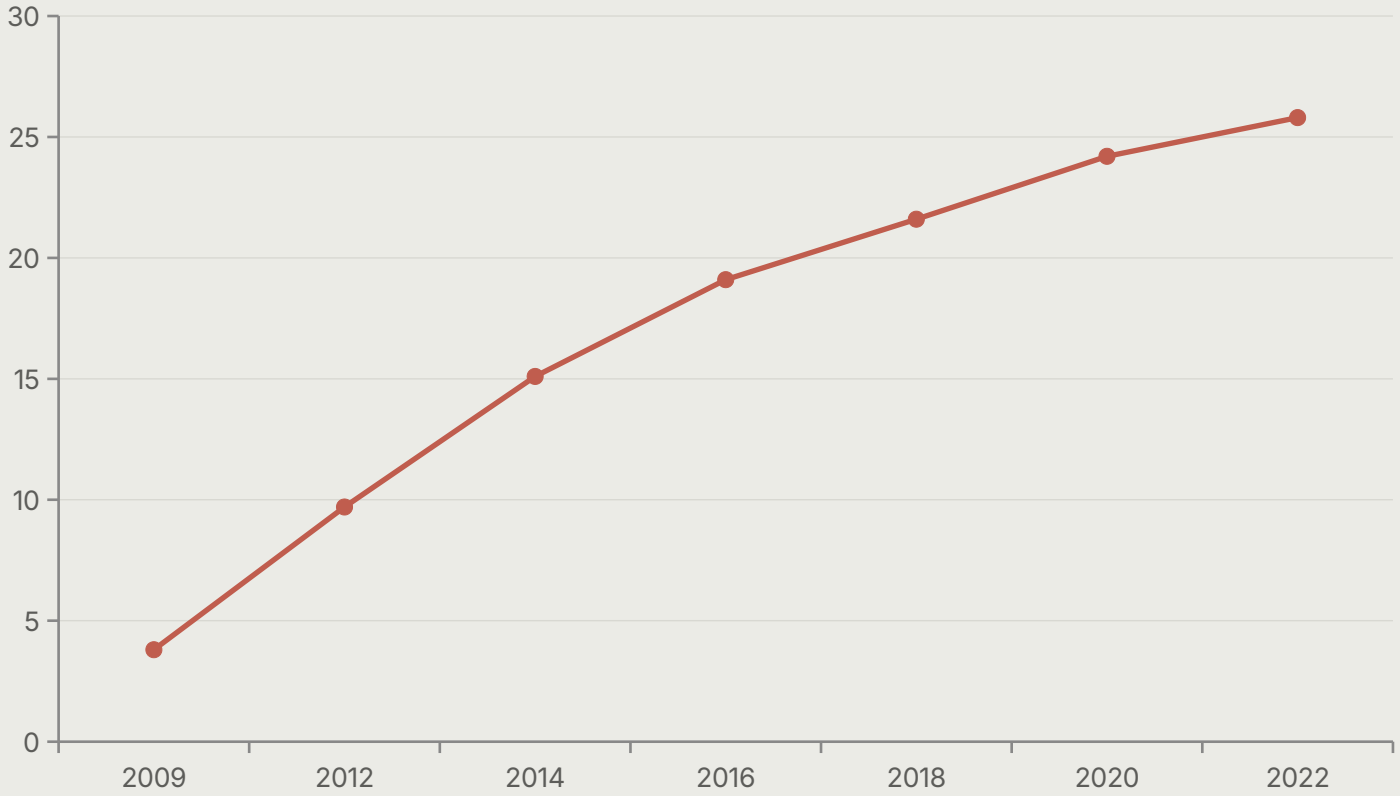
2000h+

Stable performance achieved by some devices

Under continuous 1 sun illumination at 25°C

These numbers show that while we've achieved remarkable efficiency, our stability is still far short of what's needed for commercial viability. The 25.8% efficiency vs 10-year requirement creates a 30

Efficiency Progression of Perovskite Solar Cells



- From 3.8% to 25.8% in 13 years
- Rapid efficiency gains
- Stability still lags behind

Commercial Viability

Perovskite solar cells have achieved 25.8% efficiency but must overcome stability issues to compete with commercial silicon cells.

- PSCs reach 25.8% efficiency like Si cells
- But PSCs degrade in 1000+ hours vs Si's 20+ year lifespan
- Stability challenges prevent commercialization despite high performance

Stability: The Key to Perovskite Commercialization

Without addressing stability, perovskite solar cells cannot compete with established technologies.

The path forward requires standardized testing protocols, improved materials, and scalable fabrication techniques. Only then can perovskites truly enter the commercial energy market.

Address stability now—secure perovskite's future in clean 能源