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Americas Energy & Transition

Americas Power and Energy Transition: Crystal Clear - Perovskite - Next Solar Promise?

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Perovskite is the next-generation promise in solar technology. Its promise lies in higher efficiency and potentially lower manufacturing costs than traditional silicon panels. The primary barrier to commercialization has been stability, namely consistent performance without degradation under varying conditions.

We hosted Scott Wharton, CEO of Tandem PV in our office this week - Tandem PV is a private US company that is working to commercialize perovskite at scale in the US. *This note is a mix of the conversation this week, and our own research.*

Coverage read-through: this is most directly relevant to FSLR (Oxford PV license as a defensive hedge to the CdTe development, along with internal R&D and a pilot line), with second-order relevance to TE (US Si manufacturing story).

Key takeaways:

Perovskite as a material absorbs light extremely efficiently. As a tandem material with silicon, they have higher efficiencies than any panel currently on the market.

They are soft and easy to process, **making them cheap to manufacture**.

The same soft, ionic lattice that makes them cheap to process, makes them chemically fragile - moisture, heat, natural elements all degrade the crystal structure over time. **Bankability is the main concern** - being able to make panels that last 20 plus years is the holy grail.

Commercialization appears to be most likely around 2028.

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BERNSTEIN TICKER TABLE

			30 Jul 2026		TTM		Reported EPS			Reported P/E (x)		
			Closing	Price	Rel.							
Ticker	Rating	Cur	Price	Target	Perf.	Cur	2025A	2026E	2027E	2025A	2026E	2027E
FSLR (First Solar)	U	USD	206.01	197.00	(1.9)%	USD	14.21	16.26	19.96	14.5	12.7	10.3
TE (T1 Energy)	M	USD	4.27	9.00	214.1%	USD	(2.19)	(0.31)	(0.07)	(1.9)	(13.6)	(59.4)
SPX			7,437.63									

O - Outperform, M - Market-Perform, U - Underperform, NR - Not Rated, CS - Coverage Suspended

Source: Bloomberg, Bernstein estimates and analysis.

INVESTMENT IMPLICATIONS

We are Underperform on FSLR with a price target of $197.

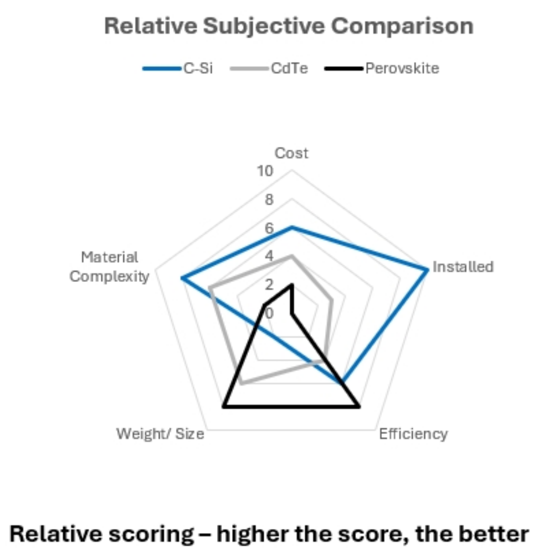
We are Market-Perform on TE with a price target of $9.

DETAILS

WHAT IS PEROVSKITE?

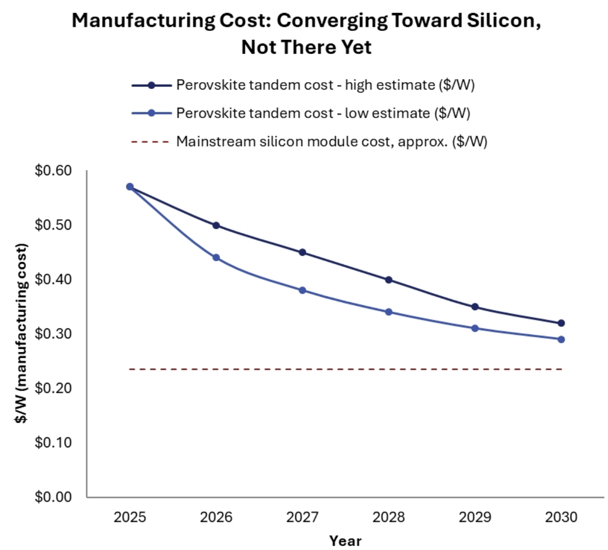
Perovskite is a material that absorbs solar energy with higher efficiency than the current incumbents of silicon or cadmium telluride. The crystal structure - ABX3 - a large cation (A) and smaller cation (B) pack with an anion (X) in a repeating cage-like lattice, was discovered in the 1800s by mineralogist Lev Perovski. The original mineral is calcium titanate (CaTiO3) and available naturally in the earth's crust (if you drill deep enough). **Perovskites used in solar cells today are almost entirely synthetic metal-halide perovskites** — not the original calcium titanate mineral. The workhorse composition is a hybrid organic-inorganic lead halide, most commonly methylammonium or formamidinium lead iodide, with the halide chemistry (iodide, bromide, chloride, or a mix) tuned to set the material's bandgap.

EXHIBIT 1: **Subjective Comparison Between CSi, CdTe and Perovskite**



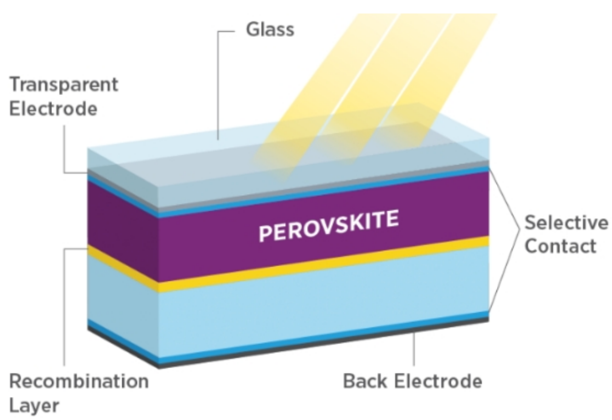
Source: Bernstein Analysis

EXHIBIT 2: **Perovskite Manufacturing Cost**



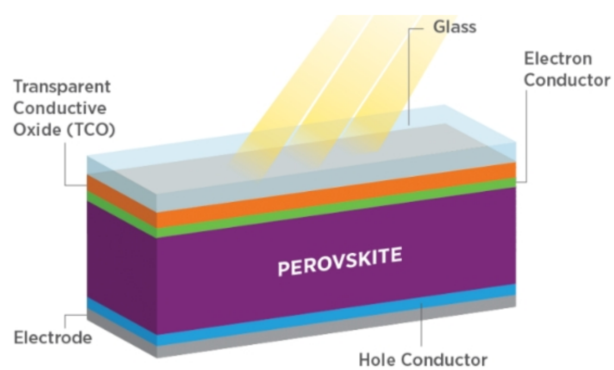
Source: Astute Analytica, Bernstein Analysis

EXHIBIT 3: **Perovskite on Tandem Silicon Cell**



Source: US DOE

EXHIBIT 4: **Thin Film Perovskite Solar Cell**



Source: US DOE

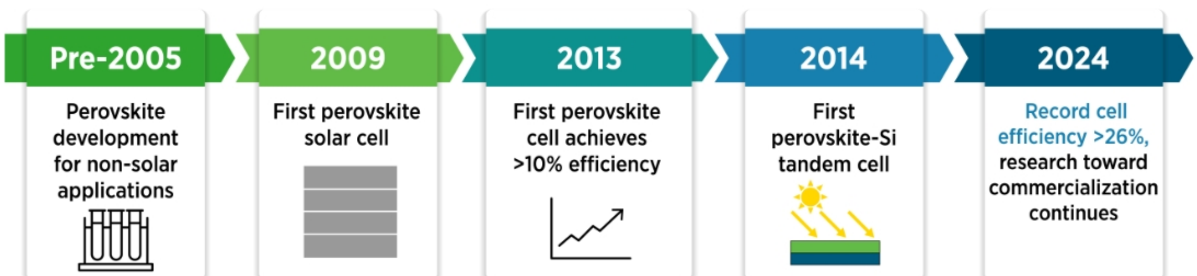
HOW ARE THEY DIFFERENT FROM CURRENT PANELS?

Perovskites are a tunable, solution-processed thin-film absorber family, whereas CdTe is a single inorganic semiconductor and crystalline silicon is a thick, wafer-based, mature technology with very different manufacturing, band-gap, and reliability profiles.

The core material and manufacturing processes have become stable enough for commercialization in the next few years.

- Perovskite: Refers to a class of "metal-halide perovskites" with ABX3 crystal structure, typically hybrid organic–inorganic compounds such as lead halides; the term is about structure, not a single material
- CdTe: A specific compound semiconductor (cadmium telluride) with fixed composition, used as the absorber in thin-film modules
- Crystalline silicon: Elemental semiconductor (c-Si) in mono or multi-crystalline wafer form, the incumbent PV technology with decades of field data and standardized supply chains (~90+% of global panels are silicon panels)
- 20%-25%-30% is an easy way to remember the approximate efficiencies of cadmium telluride, crystalline silicon, and perovskite solar panels, respectively
- When perovskite is used in tandem to a silicon panel, it doesn't add much weight, but increases the efficiency by ~30%
- Why does efficiency matter? Any change has a huge impact on the LCOE, and overall deployment cost. If you have a higher efficiency panel, you need less land, labor, panels. So you can potentially charge a premium and still be cheaper

EXHIBIT 5: **Perovskite timeline**



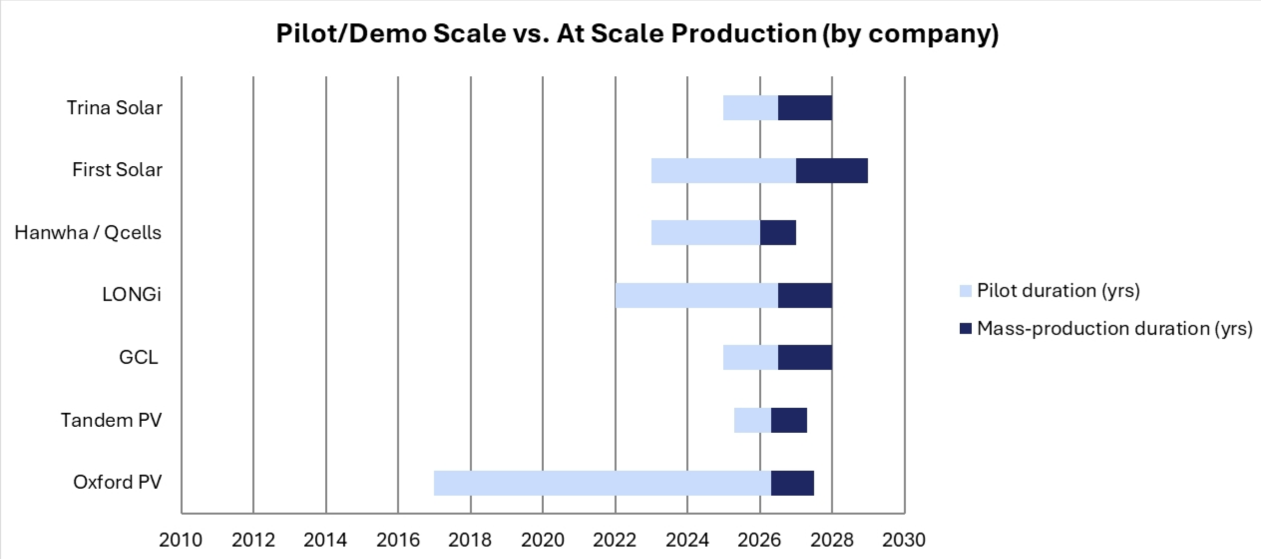
Source: US DOE

COMPETITIVE LANDSCAPE

Two architectural camps have emerged. Two-terminal (2T) monolithic tandems (Oxford PV, LONGi, most Chinese companies) deposit the perovskite directly onto the silicon cell in a single stack with one electrical interface — simpler for module and inverter integration, but the two subcells are electrically coupled and manufacturing yield risk sits in one integrated process.

Four-terminal (4T) designs (Tandem PV, GCL's stated preference) keep the perovskite and silicon cells electrically independent, which theoretically allows for any crystalline silicon cell use — TOPCon, HJT, PERC, or IBC — letting the tandem ride silicon's own ongoing efficiency gains rather than locking into one silicon roadmap.

EXHIBIT 6: **Implied Perovskite Timeline by Company**



Source: Company filings, PV Tech, Perovskite info, Bernstein Analysis

EXHIBIT 7: **Competitive landscape in Perovskite Development**

Company	Architecture	Best certified efficiency	Commercialization status (Jul 2026)	Strategic angle
Oxford PV	2T monolithic	29.5% cell / 26.9% module	First commercial shipment (Sep 2024); 100MW Brandenburg line; GW site targeted 2026-27; MP guided 2027	Deepest IP position (400+ patents); licensing Trina (China) and First Solar (US) - ARM-style royalty model
Tandem PV	4T (perovskite glass + Maxeon IBC cell)	30.4% mini-module (internal, in 3rd-party cert.)	Fremont, CA demo line opened Apr 2026; targeting utility-scale customers in 2026	US-based, cell-agnostic (TOPCon/HJT/PERC/IBC); $64-68M raised; backed by Constellation
GCL Optoelectronic	4T, glass-glass	29.5% tandem module (large-area, TUV-certified)	1GW Kunshan line live Jun 2026; shipping 50-70MW by Q3 2026; 2GW planned	China's furthest-along GW-scale line; targets sub-$0.20/W within two years
LONGi Green Energy	2T monolithic	35.5% cell (ESTI-certified, Jul 2026)	No public mass-production date disclosed as of mid-2026	Efficiency record leader by wide margin; also #1 in HJT silicon; optionality play
Hanwha / Qcells	2T, converted Si lines	28.6% commercial-size wafer, IEC/UL passed	Commercial production targeted 2026; mass production H1 2027	Only integrated ingot-to-module US producer; retrofits existing capacity
First Solar	Thin-film perovskite (non-Si stack)	Undisclosed	R&D line in Perrysburg, OH; licensed Oxford PV US patents Feb 2026; excludes crystalline-Si tandems	Defends CdTe franchise; optionality hedge via licensing rather than a tandem bet
Trina Solar	2T, Oxford PV-licensed	808W module, TUV SUD-certified	Exclusive China license from Oxford PV (Apr 2025); scaling with Oxford IP	Distribution and manufacturing muscle paired with borrowed IP

Source: NREL, PV TECH, Green Fuel Journal, Bernstein Analysis

OPPORTUNITIES

- Land- and interconnection-constrained sites: higher efficiency generates more power per acre and per interconnection slot - valuable wherever land/queue position, is the binding constraint
- Brownfield repowering: aging utility-scale sites nearing end of PPA/equipment life are candidates for a higher-efficiency replacement extracting more output from an already-permitted footprint
- Riding silicon's own roadmap: 4-terminal architecture (Tandem PV, GCL) keeps benefiting from ongoing silicon cell improvements rather than freezing the silicon side in place

- US reshoring narrative: Tandem PV, T1 Energy, and others can pitch domestic tandem manufacturing as non-China-dependent
- Specialty and high-value applications: Aerospace/defense, and power-constrained data center rooftops can justify the efficiency premium well before tandem reaches silicon-competitive $/W

CHALLENGES

- Degradation: light- and heat-induced ion migration, halide segregation, and moisture ingress remain active failure modes; encapsulation engineering is the primary mitigation path in the literature through mid-2026
- Lead toxicity: standard high-efficiency recipes use lead-halide compositions; damaged/improperly encapsulated modules can leach lead; lead-free alternatives (tin-, antimony-, bismuth-based) remain behind on efficiency and stability
- Warranty gap: Companies are targeting a 20-year warranty by 2027-28 - a utility financing a 20-30 year asset needs field data that doesn't yet exist for a technology first shipped commercially in Sep 2024
- Manufacturing yield at scale: uniformity yield risk, not chemistry, is the likelier reason mass-production dates keep slipping

COMPANY SNAPSHOT: TANDEM PV

EXHIBIT 8: **Tandem PV Company Snapshot**

	Detail
Founded	2016 (Palo Alto/San Jose, CA); originally Iris PV
Founder / CTO	Colin Bailie (Stanford PhD; published first peer-reviewed perovskite-silicon tandem cell research, mid-2010s)
CEO	Scott Wharton
Co-founder	Chris Eberspacher - former CTO, Hanwha Q Cells and Applied Materials SunFab
HQ / manufacturing	Fremont, California - demonstration manufacturing line opened April 2026
Capital raised	~$100M across 7 rounds (seed, grants, Series A led by Eclipse, Mar 2025)
Key investors	Eclipse, Constellation Energy, Planetary Technologies, Uncorrelated Ventures, Trellis Climate, Stifel; angel: Tom Werner (ex-CEO, SunPower)
Government support	$4M California Energy Commission grant; additional DOE grant funding (2024)
Architecture	4-terminal: proprietary perovskite glass layer mechanically stacked atop a separately-manufactured silicon cell - cell-agnostic (TOPCon, HJT, PERC, or IBC)
Headline result	30.4% efficiency on a 100cm2 demonstration module (internal test, now in 3rd-party certification); perovskite subcell alone converts 21.7%, underlying Maxeon IBC cell retains 8.7%
Near-term target	28% efficiency at full commercial module size, aimed at utility-scale customers later in 2026
Employees	~60
Expected Customers	Sell to IPPs

Source: Bernstein Analysis

READ THROUGH TO COVERAGE UNIVERSE

First Solar (FSLR)

In February 2026, FSLR secured a non-exclusive U.S. patent license from Oxford PV. It is in addition to R&D spend, the 2023 Evolar acquisition, and a dedicated perovskite development line in Perrysburg, Ohio — and it explicitly excludes crystalline-silicon tandem architectures.

We view the Oxford PV license as a defensive move signaling FSLR's internal perovskite R&D may not have met management's commercialization thresholds, despite significant R&D spend. If perovskite continues to progress on the 2028 timeline, FSLR could face a threat of substitution.

T1 Energy (TE) — not a technology overlap, potential partner down the road?

TE's FEOC-compliant, 45X-eligible US solar manufacturing thesis and Tandem PV's US-based tandem manufacturing thesis are both playing the same 'reshore capital-intensive solar manufacturing under IRA/45X support' strategy without being direct competitors. Our view is that TE could ultimately partner with a perovskite developer as the technology matures.

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First Solar, Inc.

We use a SOTP valuation applying 1) a 9x multiple on gross margin without tax credits, 2) Tax credits phasing out starting in 2030 3) a 10% discount rate on backlog, 4) a 12% discount rate on TOPCon licensing as an option, and 5) we add a probability weighted cash component. We arrive at a target price of $197/sh.

T1 Energy Inc.

We use an 8x multiple on probability weighted 2030 EBITDA of $660MM in the bull case (30%), $560MM in the base case (40%) and $280MM in the bear case (30%) to arrive at a target price of $6/sh.

RISKS

First Solar, Inc.

Upside risks to our price target include 1) the extension of 45x tax credits beyond 2030, 2) A favorable outcome to the TOPCon patent action against C-Si competitors to FSLR in the U.S. and 3) Commercialization of perovskite solar cells or significant improvement in panel efficiency driving margin improvement.

T1 Energy Inc.

Key downside risks to our price target include an unfavorable outcome from the TOPCon suit, lower future capacity expansion or lower utilization, and continued tariff risk on imports. Upside risks include stronger uncontracted margins and successful expansion of future facilities.

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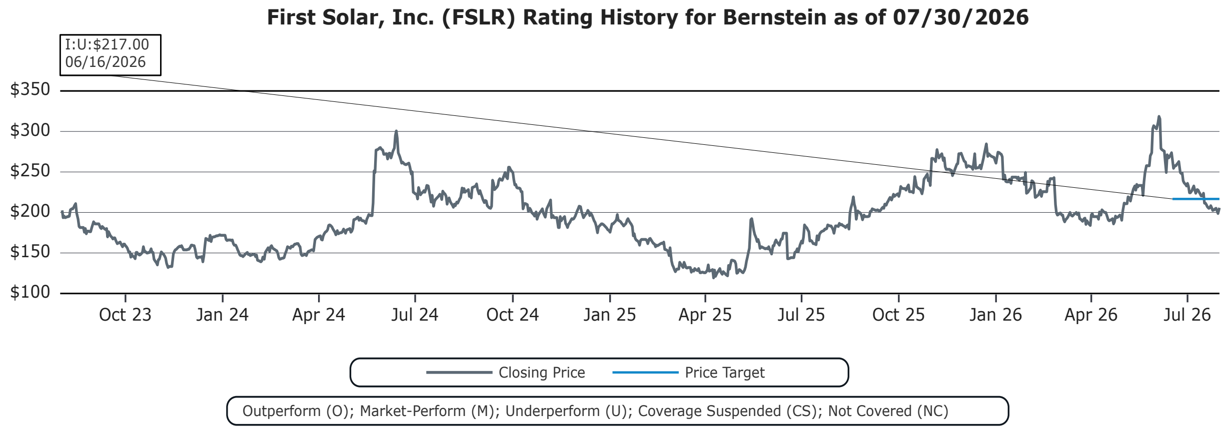

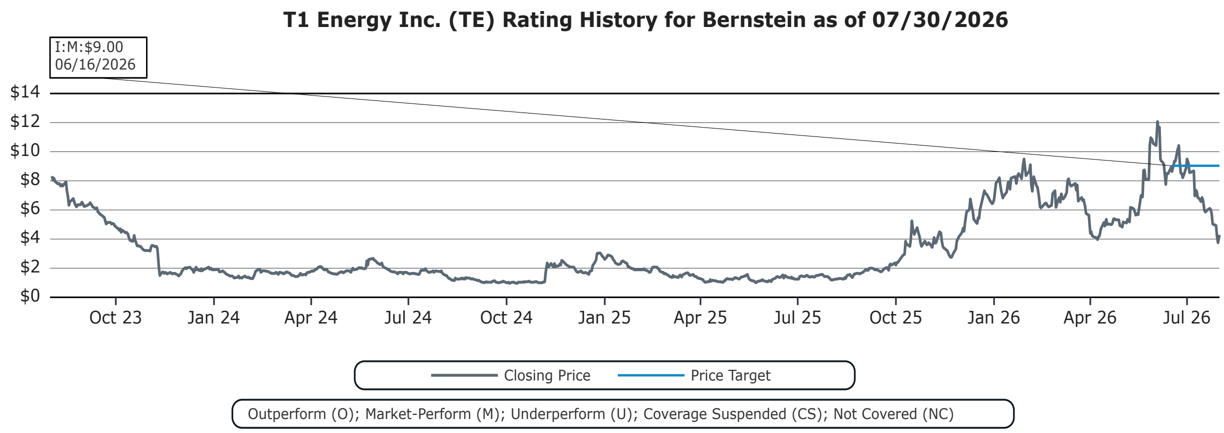

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