U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

Perovskite and OPV Solar Technologies

Motivation, Programs, and Challenges

Andrew Dawson, Technical Advisor
Solar Energy Technologies Office

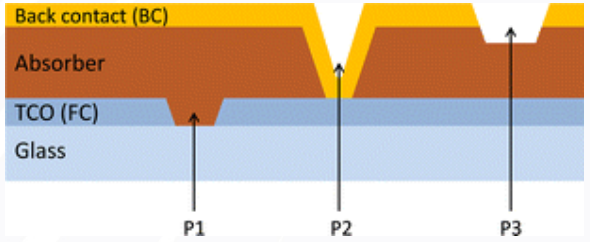
Overview:

- Perovskite and OPV Technology Overview
- Perovskites:
  - Motivation for R&D Program
  - Major Challenges
  - SETO Strategy and Portfolio
  - Gaps and Future Directions
- Q&A

Perovskite and OPV Solar Technologies:

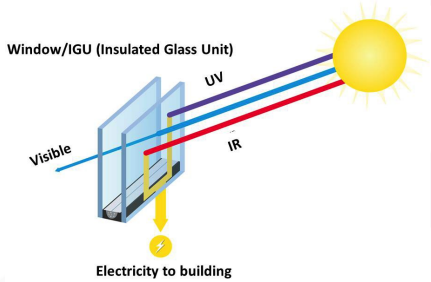
Perovskite and OPV Technologies:

- Thin-film photovoltaics, flexible deposition approaches
- Class of material or crystal structure, not a single material
- Tunable bandgaps, frequently utilized as tandems



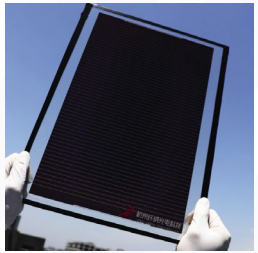
OPV:
Highly tunable bandgaps/colors
Lower efficiency
Building integrated systems

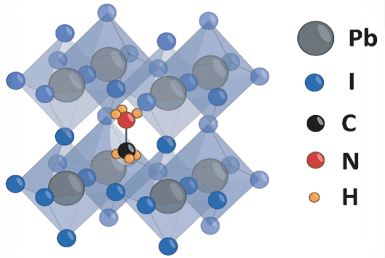
$4M Federal



Perovskites:
Higher efficiency
More flexible deposition
Electricity generation and mobile energy

$34M Federal

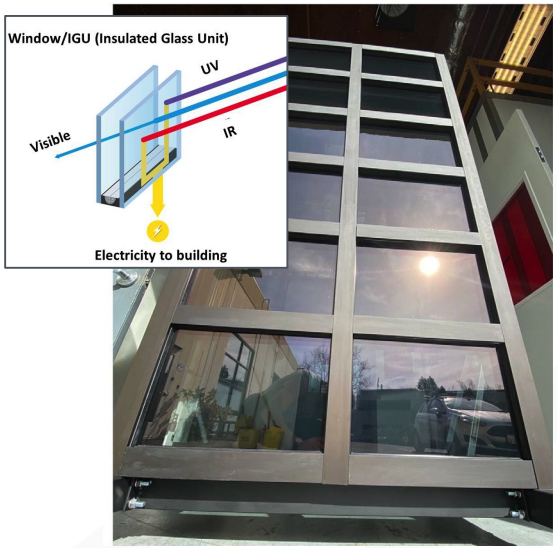




OPV Portfolio:

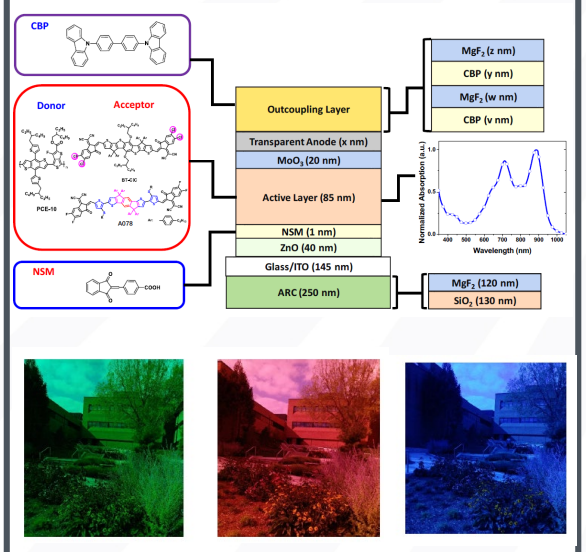
NEXT

PI: Corey Hoven



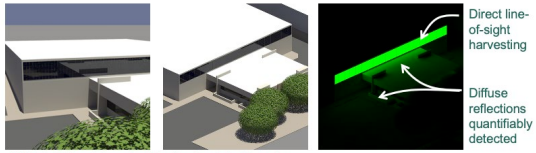
UNIVERSITY OF MICHIGAN

PI: Stephen Forrest

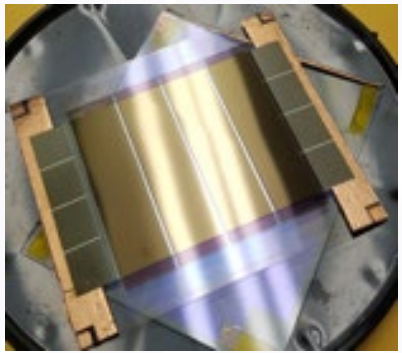


NANOFLEX POWER CORPORATION

PI: Adam Barito



TMS building, Phoenix, AZ with simulated façade



Motivation for R&D Program:

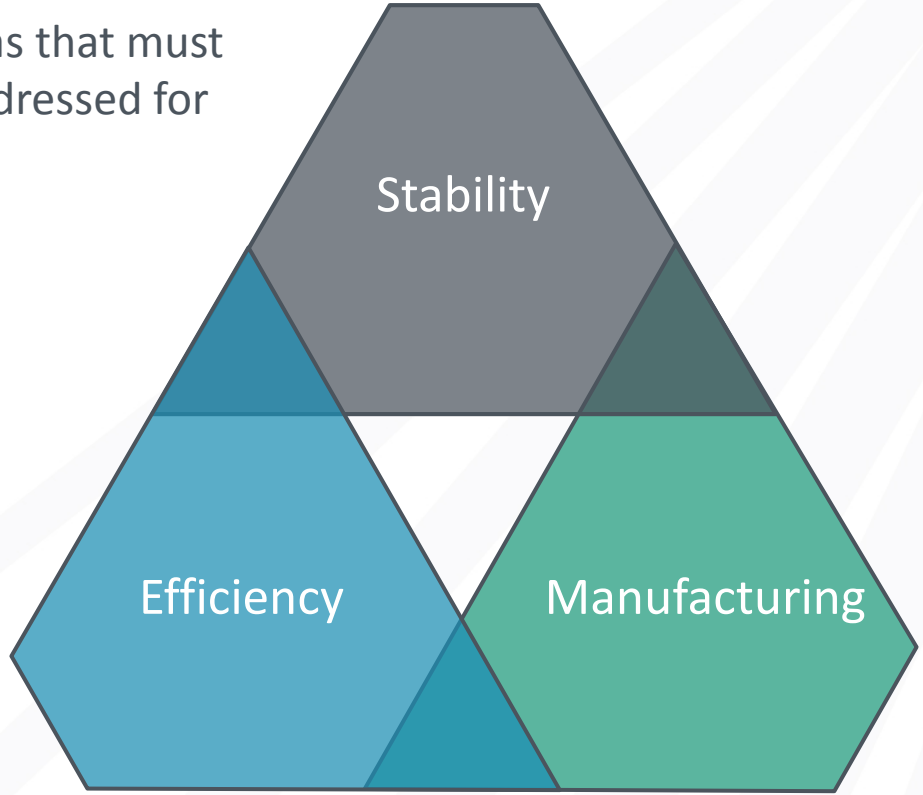
As PV deployment increases, integration costs will grow and value may erode. Incumbent technology trends may not be sufficient ensure continued competitiveness in the energy system.

- Research and develop new technologies that:
  - Can be produced more cheaply than Si or CdTe
  - Can lower LCOE through lifetime or balance of system impacts
  - Can add manufacturing capacity more quickly and cheaply

New technologies should show evidence that they will substantially improve overall competitiveness of PV in the energy system to warrant investigation

Challenge Areas:

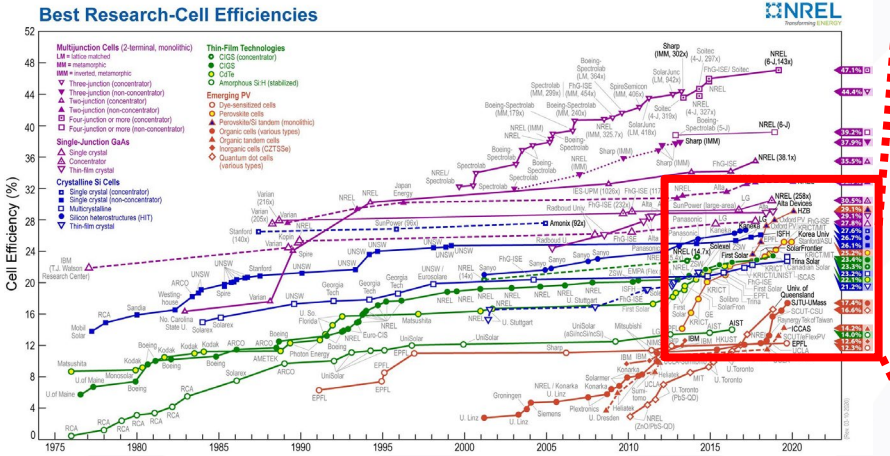
Three technical areas that must be simultaneous addressed for technology success

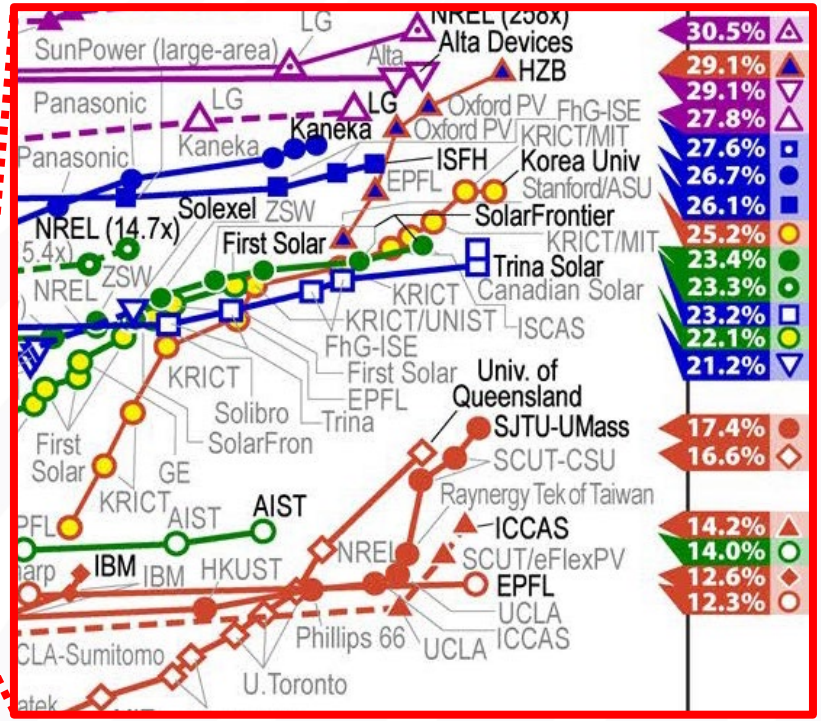


Perovskite Developments and Status:

Cell Efficiency Progress:

- 14% to 25%+ (SJ)
- 29%+ (tandem)
- Module projects targeting 18-20%





Perovskite Developments and Status:

Stability Progress:

- <10hrs to 1000hrs T80 (unencapsulated)
- Current projects targeting 10,000hrs+
- ***Test conditions are highly variable***

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

News Release: NREL Research Boosts Stability of Perovskites, Helps Silicon Solar Cells
March 5, 2020
4% PCE loss after 1000 hrs

https://www.nrel.gov/news/press/2020/nrel-research-boosts-stability-of-perovskites-helps-silicon-solar-cells.html

Perovskite Developments and Status:

Highly-Scalable Fabrication Approaches:

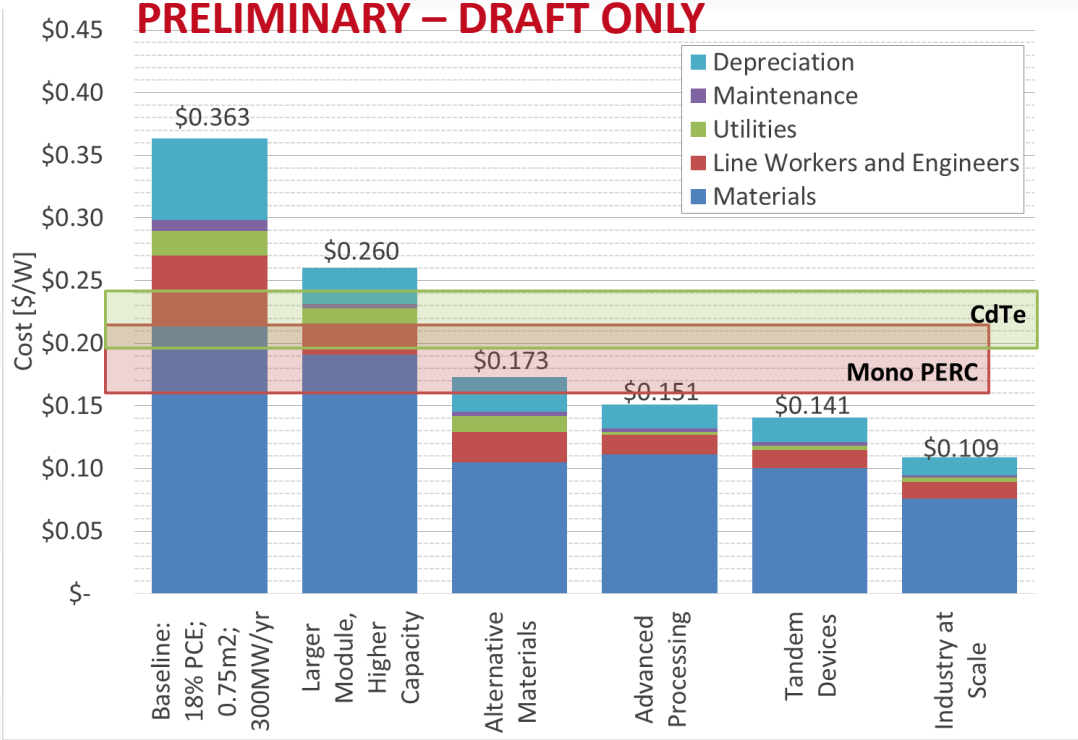
Sheet-to-Sheet

Roll-to-Roll

Motivation for R&D Program:

Production Cost Estimates:

- Multiple progressions based on current areas of R&D
- No fundamental material or process changes
- Conservative economies of scale estimates



Opportunities in Perovskite Technology Progressions.
Dawson, A., Woodhouse, M., Tinker, L. – To be submitted

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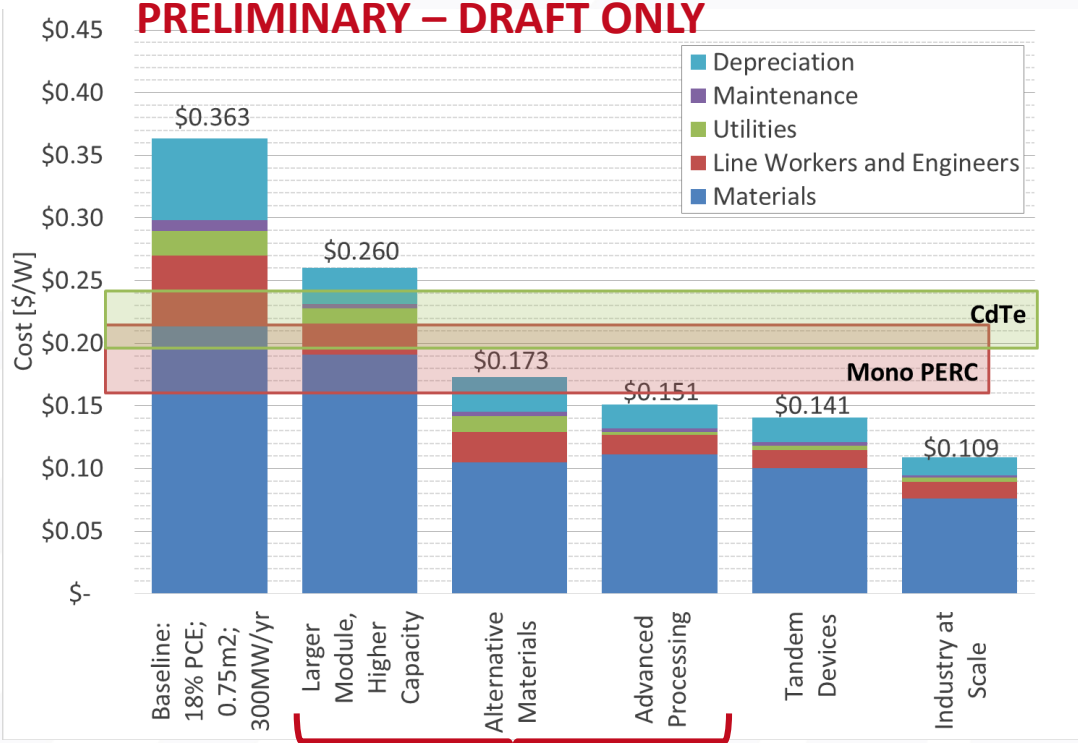


Kodak Facility: ~4GW/year

Motivation for R&D Program:

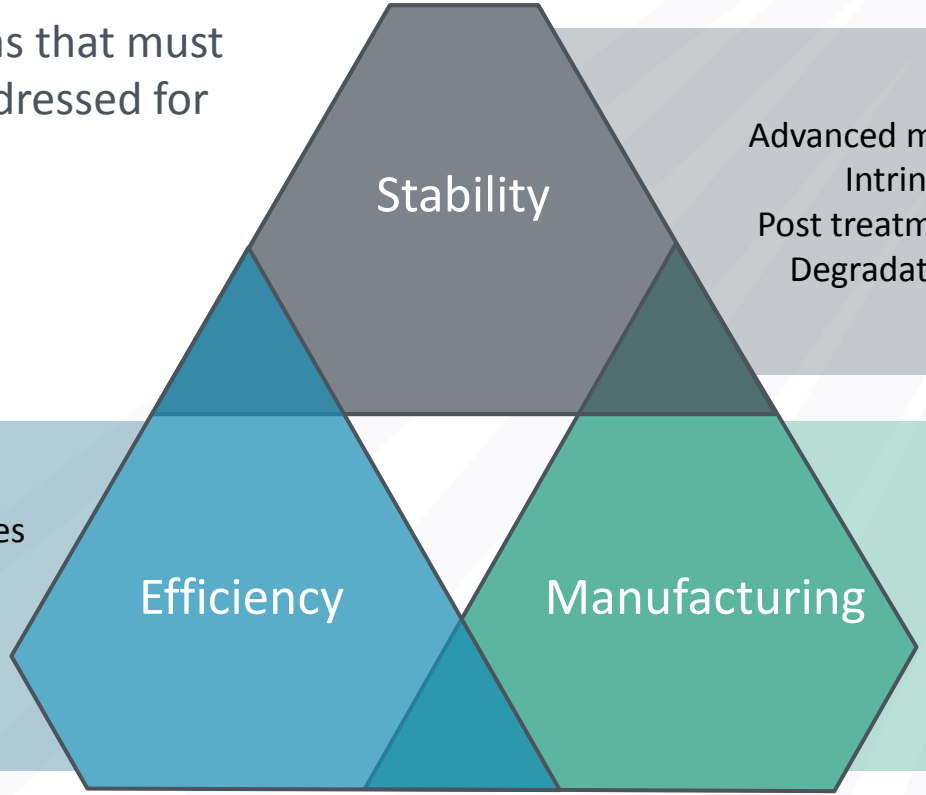
Perovskite Technologies:

- Demonstrated high efficiencies
- Multiple tandem technologies demonstrated
- Rapid improvements in stability (significant work remains)
- Compatible with multiple fabrication approaches
- Preliminary cost estimates indicate high competitiveness in:
  - Direct production costs
  - Facility capital intensity

Evidence that perovskite technologies can be high performance with low costs

Challenge Areas:

Three technical areas that must be simultaneous addressed for technology success

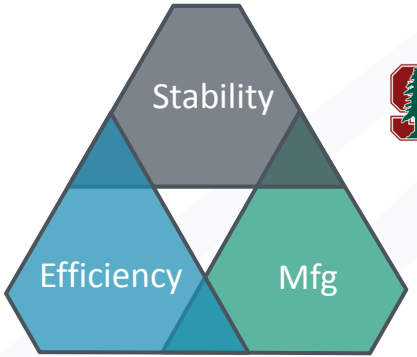


Advanced module architectures
Intrinsic material stability
Post treatment and passivation
Degradation characterization

Advanced cell architectures
Tandem devices
Material exploration
Material characterization

Process uniformity
Process repeatability
Process throughput
In-line metrology
Supply chain development

Perovskite Portfolio:

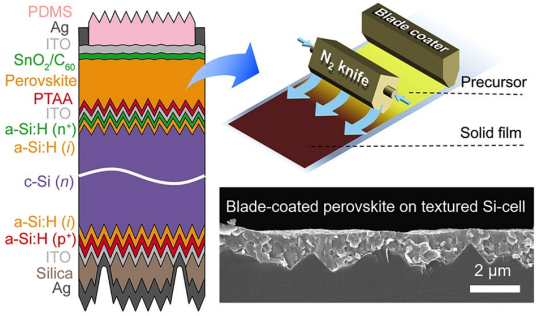


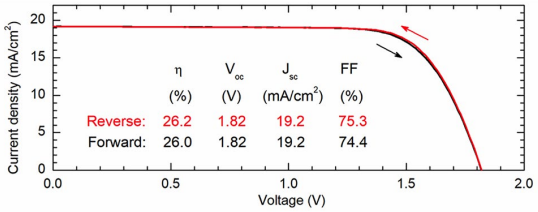
~$34M Federal
16% of portfolio

Perovskite Portfolio Highlights:

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

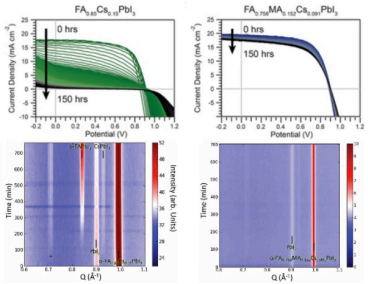
PI: Jinsong Huang





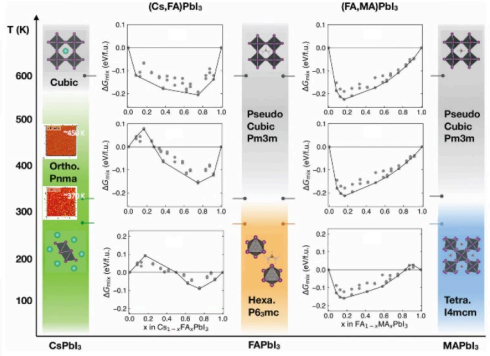
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

PI: Joe Berry



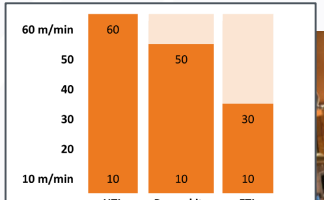
$\Delta G_{mix} > 0 \rightarrow$ no mixing

$\Delta G_{mix} < 0 \rightarrow$ stable alloy

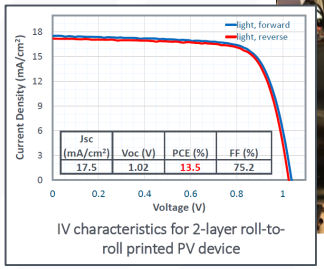


EMC Energy Materials Corporation

PI: Stephen Deluca



Range of RtR coating speeds demonstrated for key device layers



IV characteristics for 2-layer roll-to-roll printed PV device

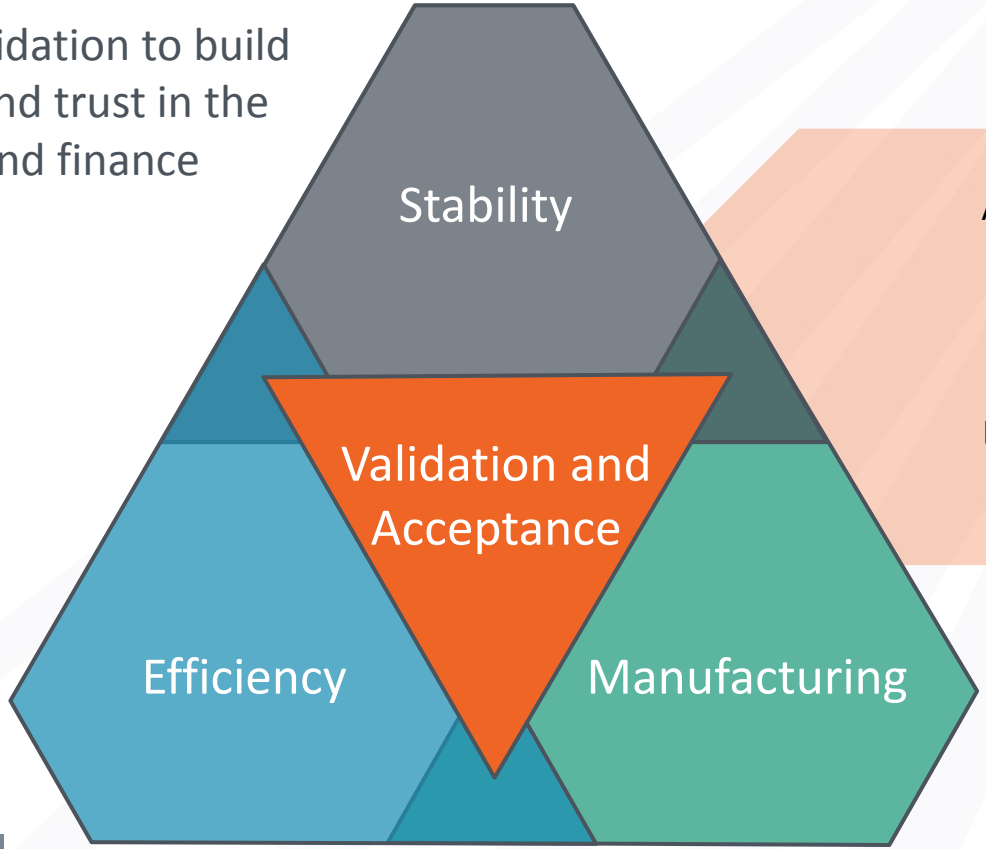
Challenge Areas:

Significant and continuing efforts to address all technical challenges for commercially relevant products, but…

… how do we establish confidence in the results?

Challenge Areas: Validation

Objective validation to build confidence and trust in the investment and finance communities



Accelerated life test protocols
Field validation
Bankability studies
Techno-economic analysis
Life cycle analysis
Environmental risk evaluation
Environmental risk mitigation

Challenge Areas: Validation

THE UNIVERSITY OF TOLEDO

Toward Low-Cost, Efficient and Stable Perovskite Modules
Accelerated life test protocols; Cell to module conversion

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Closing the cell to module stability testing gap
Field validation and standard protocol development

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Comparative Life Cycle Analysis of Scalable Perovskites
Energy and environmental impact assessments

NIU Northern Illinois University

On-device Lead Detention for Perovskite Solar Cells
Environmental risk mitigation

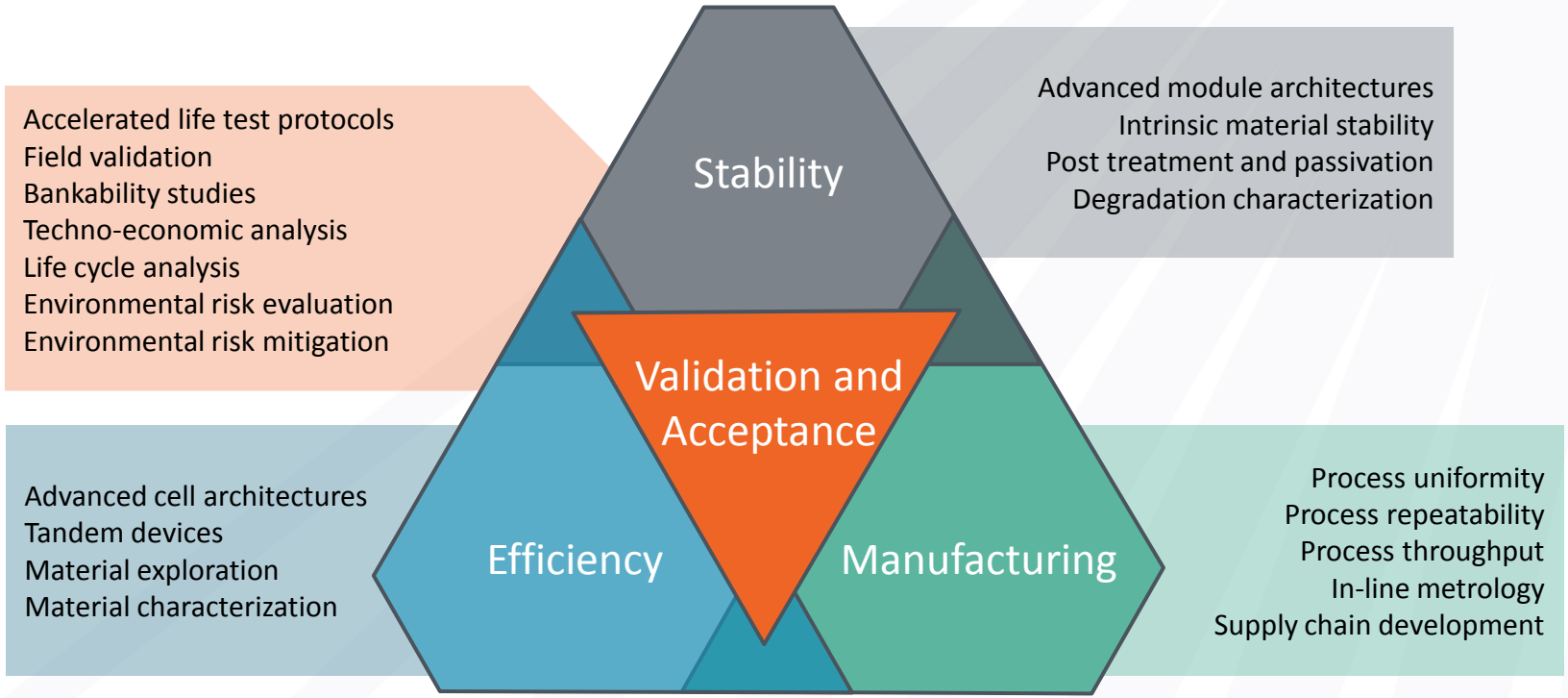
Summary:

- Perovskite technologies have demonstrated high performance as single junction and tandem devices
- Modeling shows potential for very low production costs
- Stability remains a challenge but is rapidly improving
- OPV shows differentiated value for alternative markets
- SETO strategy is focused around 4 main challenge areas:
  - Efficiency
  - Stability
  - Manufacturing
  - Validation

Structured to de-risk multiple technology facets and provide objective validation to build community trust

High-potential, High-risk, Rapidly evolving technology

QUESTIONS?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Validation and Acceptance
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Material characterization
Efficiency
Manufacturing
Process uniformity
Process repeatability
Process throughput
In-line metrology
Supply chain development