Photovoltaics Research at NREL

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NREL Photovoltaics Subprogram Lead

KIER Virtual Workshop
November 20, 2024

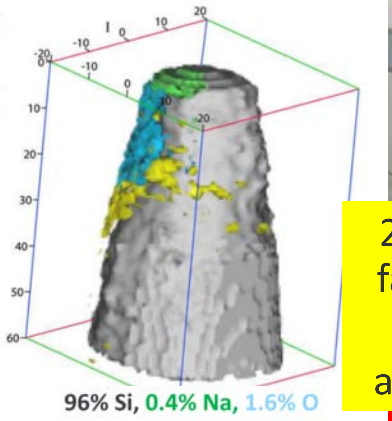
Scaling to TW

Reliability Testing for Durable PV

Ingrid.Repins@nrel.gov

1. Identify Needs:

Site Inspections, test to failure, interaction with system owners….

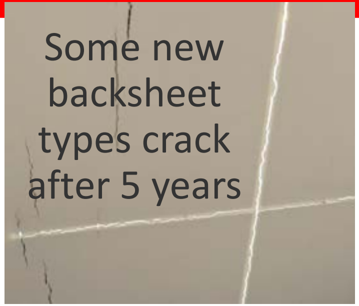


2. Understanding of failure mechanisms:

Characterization, accelerated tests, ….

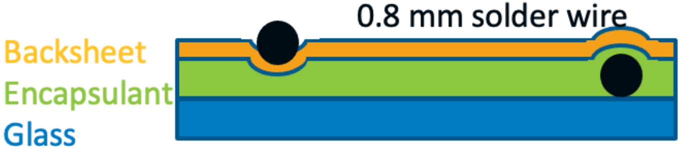
3. Transfer to commercial products:

Test protocols and standards



Some new backsheet types crack after 5 years

NREL Developed a Test to Predict



Solder Bump Test

IEC TS 62788-2 "Measurement procedures for materials used in PV modules: Frontsheets and backsheets"

DuraMAT Overview

Teresa.Barnes@nrel.gov & Laura.schelhas@nrel.gov

DuraMAT
Durable Module Materials Consortium

Consortium of **DOE national labs, universities,** and the **PV** and **supply-chain industries**

Central Data Resource

Technoeconomic analysis guides DuraMAT directions

Zuboy 2022

Multi-Scale, Multi-Physics Modeling

Mechanical models determine gridline wear-out mechanisms

Joe 2022

Disruptive Acceleration Science

Determined acceleration factors for combined accelerated stress testing

Hacke 2022

Fielded Module Forensics

Development of tool for rapid contact-free cell crack detection

Silverman 2022

Module Material Solutions

Assessed laser welding of glass-glass module seals

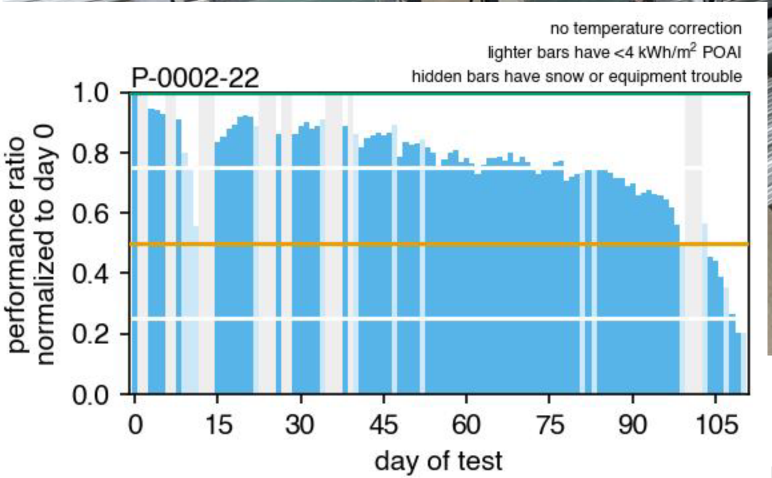
Young 2022

Perovskite PV Accelerator for Commercializing Technologies (PACT)

Laura.schelhas@nrel.gov

Key Results to date:

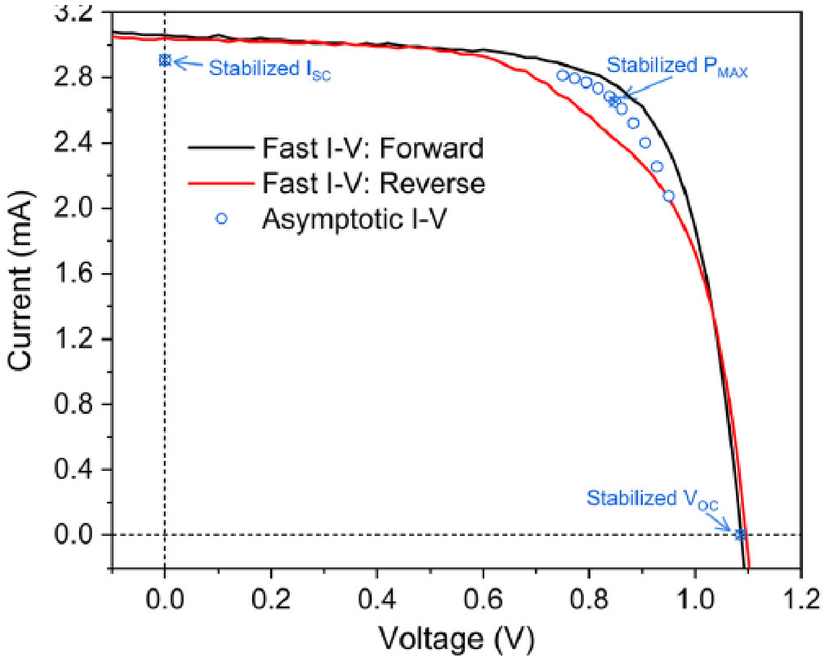
- Over 125 modules tested
- Outdoor tests demonstrating 2-3 month performance stability for university modules
  - PIB, Glass/Glass (no polymer encapsulant)
- Indoor testing:
  - Thermal cycling
  - UV
  - Light and elevated temperature



Perovskite Performance Measurement

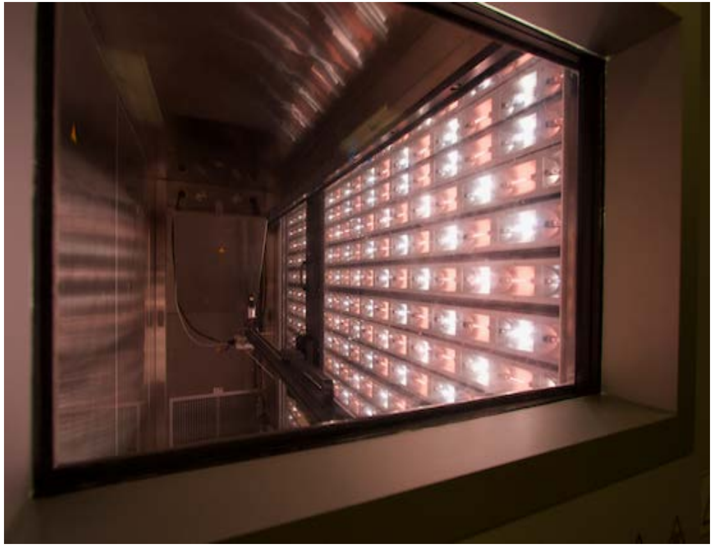
Nikos.Kopidakis@nrel.gov

Development of measurement methods that work for perovskite cells…



Song 2021, 2022

… and modules

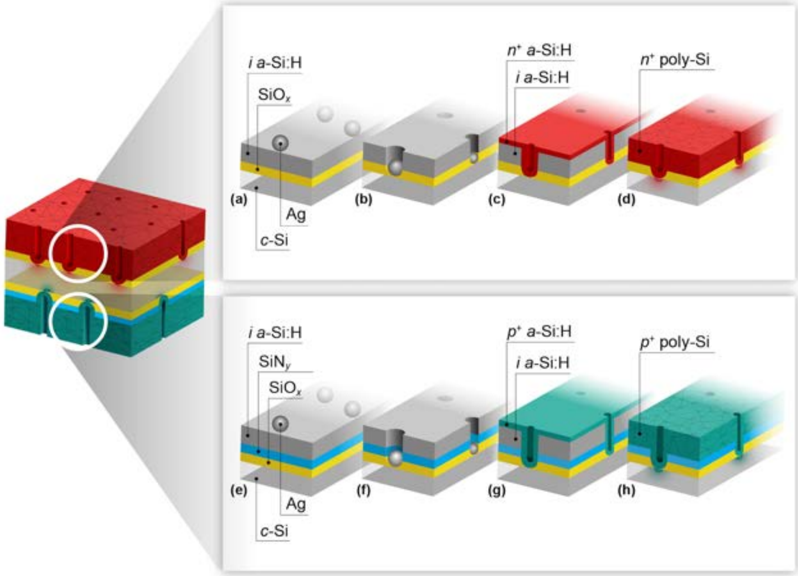


Temperature-controlled solar simulator

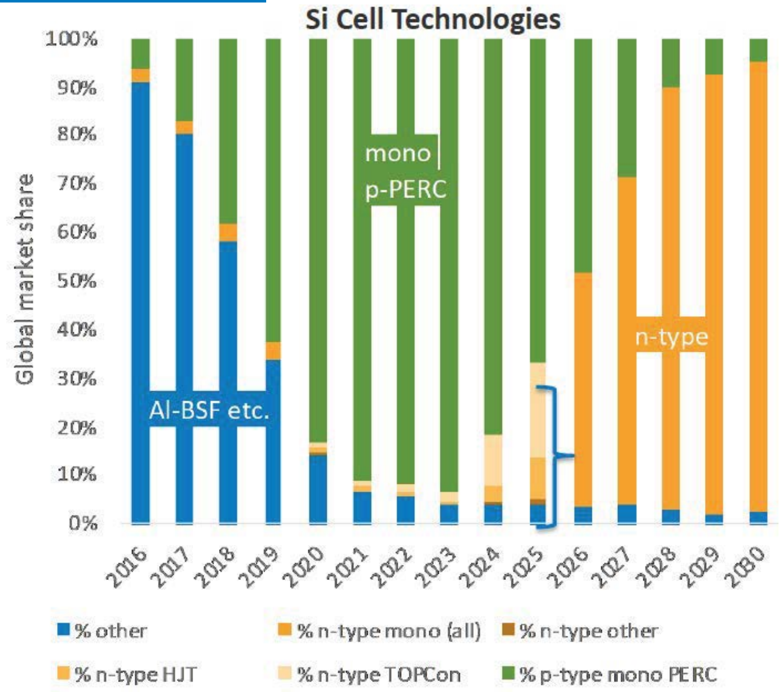
Silicon PV - Manufacturability and Performance

Paul.stradins@nrel.gov, David.Young@nrel.gov

Industrially relevant novel "PLENO" passivated contact providing high Voc and FF



USPTO app. No. 17/516,533; Anderson, AEM 2023



Zuboy 2022 – DuraMAT Tech Scouting

CdTe

Matt.Reese@nrel.gov

nature energy ARTICLES
PUBLISHED: 29 FEBRUARY 2016 | ARTICLE NUMBER: 16015 | DOI: 10.1038/NENERGY.2016.15

CdTe solar cells with open-circuit voltage breaking the 1 V barrier

J. M. Burst[1], J. N. Duenow[1], D. S. Albin[1], E. Colegrove[1], M. O. Reese[1], J. A. Aguiar[1], C.-S. Jiang[1], M. K. Patel[2], M. M. Al-Jassim[1], D. Kuciauskas[1], S. Swain[3], T. Ablekim[3], K. G. Lynn[3] and W. K. Metzger[1]*

First Solar

CdTe Accelerator Consortium

2016:
- Science-driven defect-chemistry breakthrough gives >1V Voc, far improved stability
- Low TRL, single crystal, not manufacturable

Present:
- Concept transferred to manufacturable poly-CdTe
- First Solar phasing into production

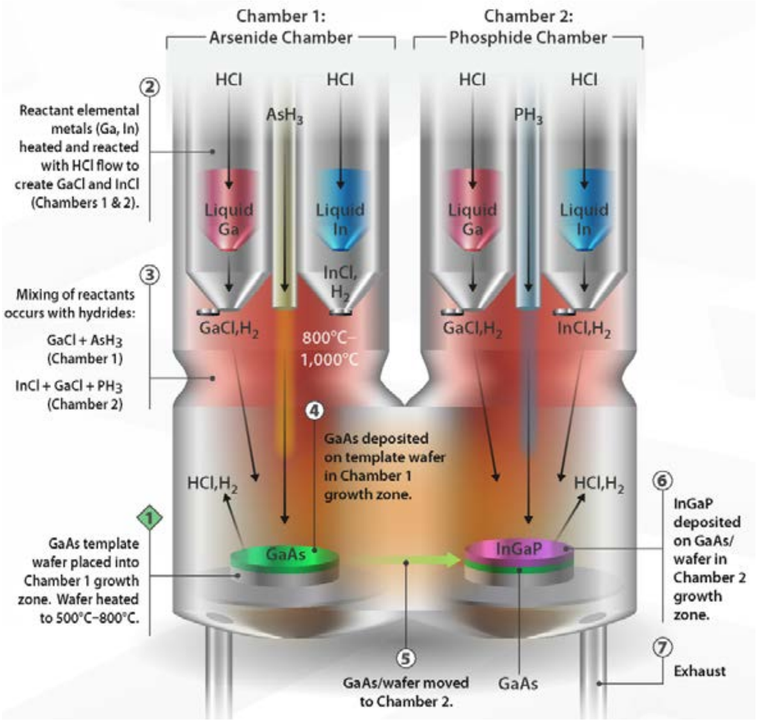
Next Steps:
- Realize full potential Voc boost
- 25+% efficient production cells

US-MAC
Manufacturing of Advanced Cadmium Telluride

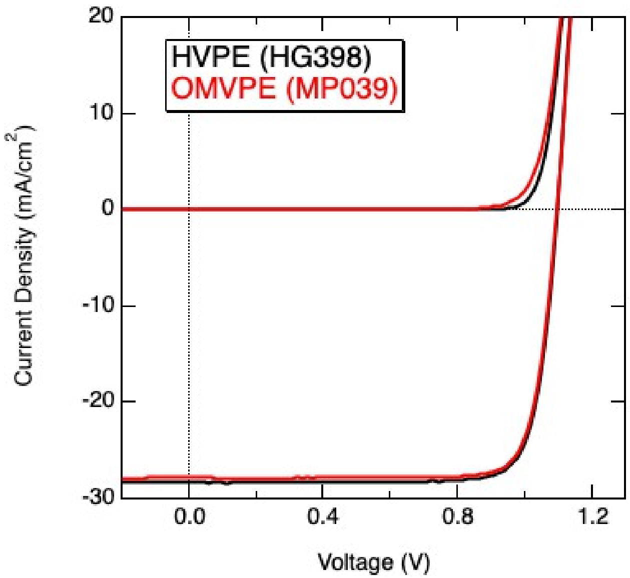
III-V Manufacturing – Scaling and Cost Reduction

Aaron.Ptak@nrel.gov

Hydride Vapor Phase Epitaxy (HVPE): much faster deposition and less-costly feedstocks



Comparison of HVPE- and OMVPE-grown solar cells with the same structure show nearly identical performance



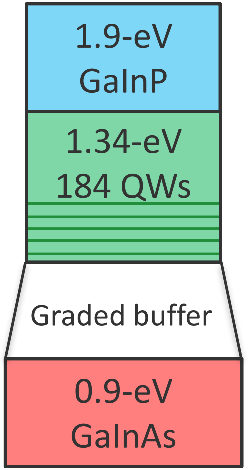
Reaching for Limits of Tandem Performance

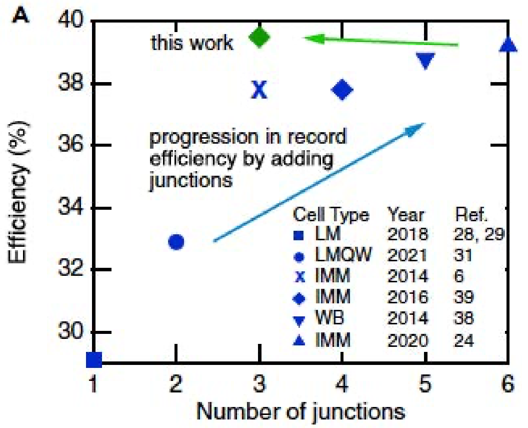
Myles.Steiner@nrel.gov, Joe.Berry@nrel.gov

Established
III-V

Emerging
perovskite

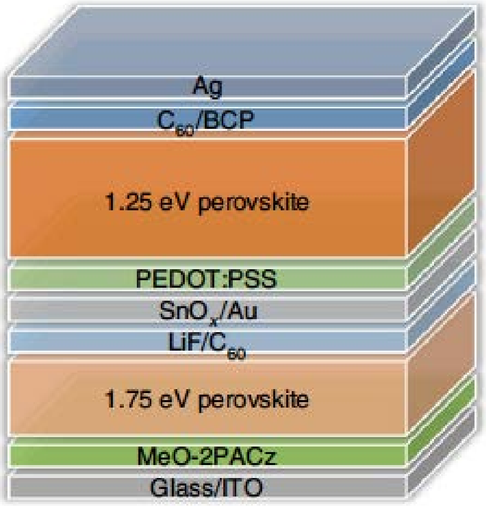
39.5% record eff, with only 3 junctions





France 2022

27.1%-efficient all-perovskite tandem

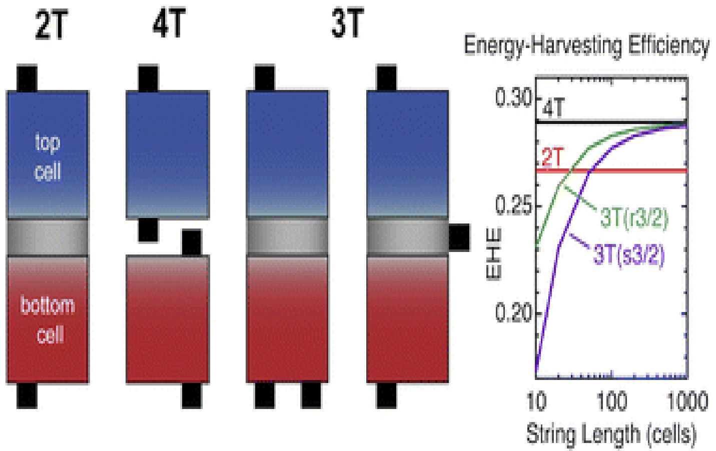


Jiang 2022 Tong 2022

Tandems – "X on Y" PV for Next Generation Performance at TW-compatible Costs

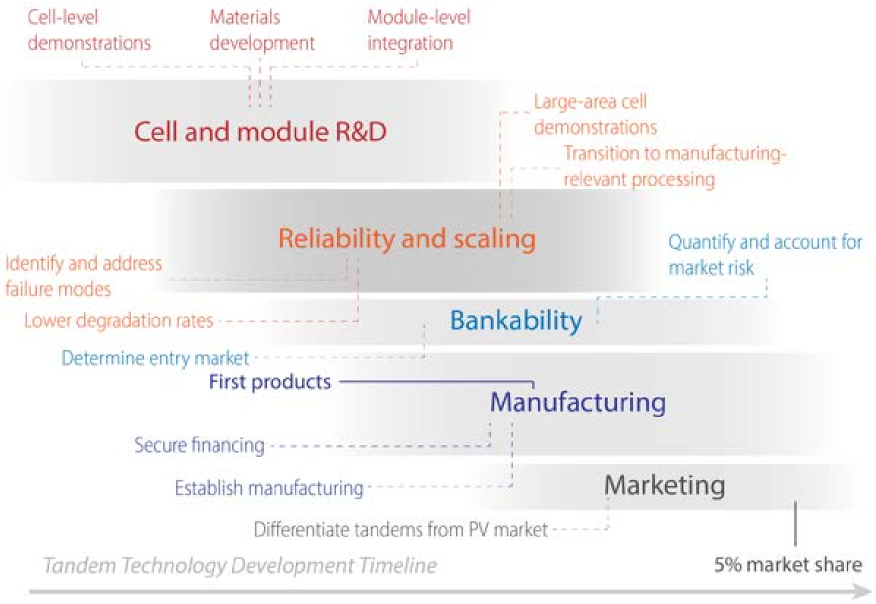
Design rules and harvesting analysis for comparing tandem architectures

- https://github.com/NREL/PVcircuit



McMahon 2023

Tandems cost / performance / reliability roadmap published



Alberi 2024

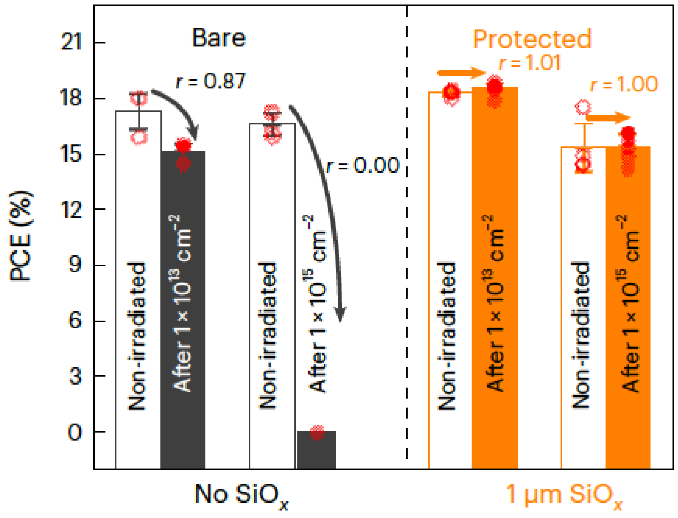
PV Everywhere

Perovskites for Space Applications – Radiation Hardness and Testing

Joey.Luther@nrel.gov

- *Low*-energy protons key to perovskite radiation testing and hardening
- Thin/lightweight 1-µm SiO_2 barrier provides significant radiation hardening
- Benefits to weight and cost, vs conventional cover glass

1-µm SiO_2 layer hardens against 0.05 MeV protons at $10^{15}/cm^2$

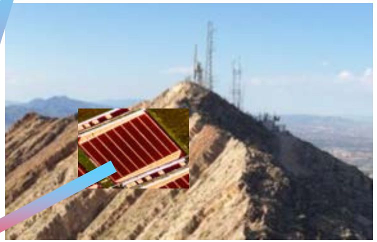


Kirmani 2023

Laser Power Conversion (LPC)

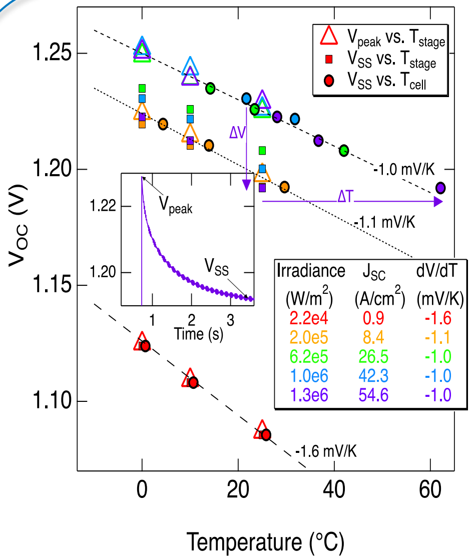
What and Why

Unlimited flight duration

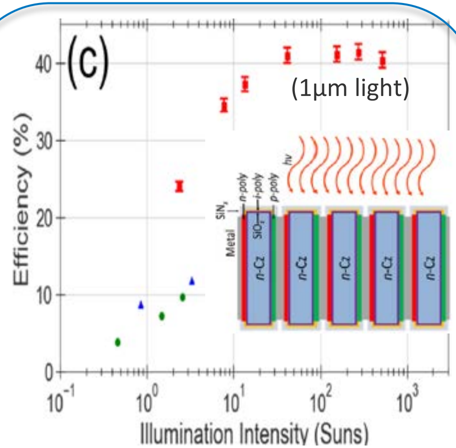


Remote / emergency power

And many other applications



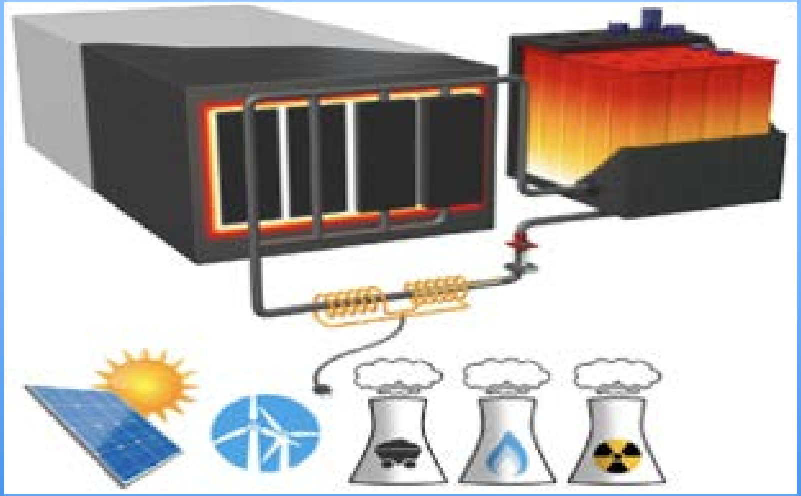
Methods for determining junction performance and temperature (Geisz 2023)



Development of 40% eff. silicon LPC (Hartenstein 2023)

Converting, Harvesting, and Storing Thermal Energy with TPV

Utility-scale energy storage



Industrial waste heat recovery

ANTORA

MIT

Nature

Thermophotovoltaic efficiency of 40%

LaPotin 2022

https://doi.org/10.1038/s41586-022-04473-y

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Alina LaPotin[1], Kevin L. Schulte[2], Myles A. Steiner[2], Kyle Buznitsky[1], Colin C. Kelsall[1], Daniel J. Friedman[2], Eric J. Tervo[2], Ryan M. France[2], Michelle R. Young[2], Andrew Rohskopf[1], Shomik Verma[1], Evelyn N. Wang[1] & Asegun Henry[1]

Joule

Efficient and scalable GaInAs thermophotovoltaic devices

Tervo 2022

Eric J. Tervo,[1,4] Ryan M. France,[1] Daniel J. Friedman,[1] Madhan K. Arulanandam,[1,2] Richard R. King,[2] Tarun C. Narayan,[3] Cecilia Luciano,[3] Dustin P. Nizamian,[3] Benjamin A. Johnson,[3] Alexandra R. Young,[3] Leah Y. Kuritzky,[3] Emmett E. Perl,[3] Moritz Limpinsel,[3] Brendan M. Kayes,[3] Andrew J. Ponec,[3] David M. Bierman,[3] Justin A. Briggs,[3] and Myles A. Steiner[1,5,*]

Thank you

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