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Silicon Solar Cells: Recent Advances and Remaining Challenges

Dr David Payne

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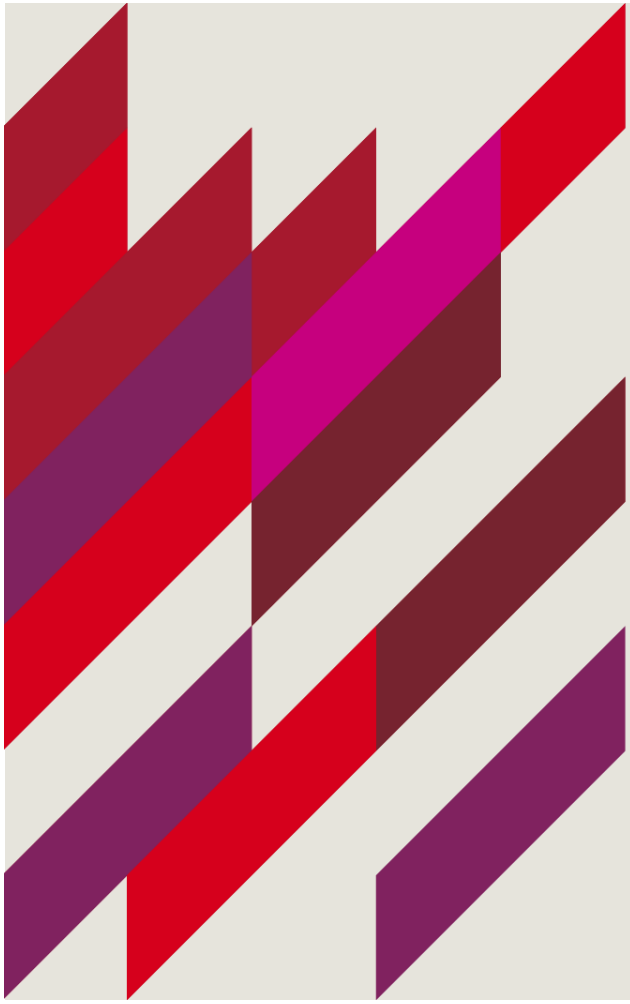

1. Introduction – Our MQ PV group
2. Overview of the silicon PV journey so far
3. Recent advances
4. Enduring challenges
5. What comes next?

The MQ PV Group

OUR TEAM

- Over the last few years, multiple PV researchers have joined engineering at MQ
- We work across three main labs on campus which include commercial and custom fabrication and characterisation tools
- We currently run several funded projects across various PV areas, including silicon and thin-film/next-gen approaches

Darren Bagnall

Shujuan Huang

David Payne

Binesh Puthen-Veettil

Mattias Juhl

+ Ngoc Duy Pham, Lin Yuan, Long Hu, Jianghui Zheng

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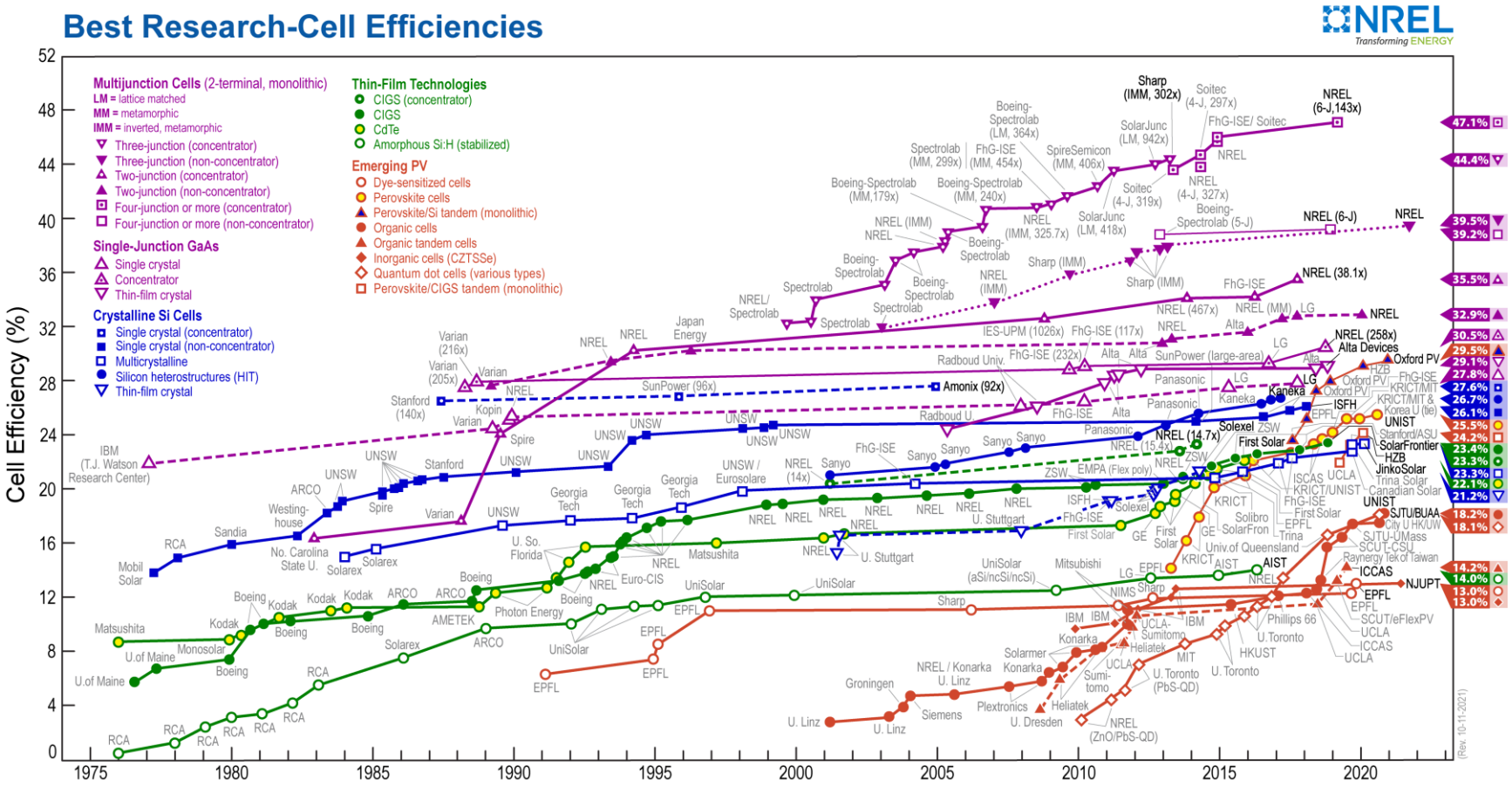
The silicon PV journey so far

Overview of PV

A DIVERSE FIELD



Source: NREL

Overview of PV

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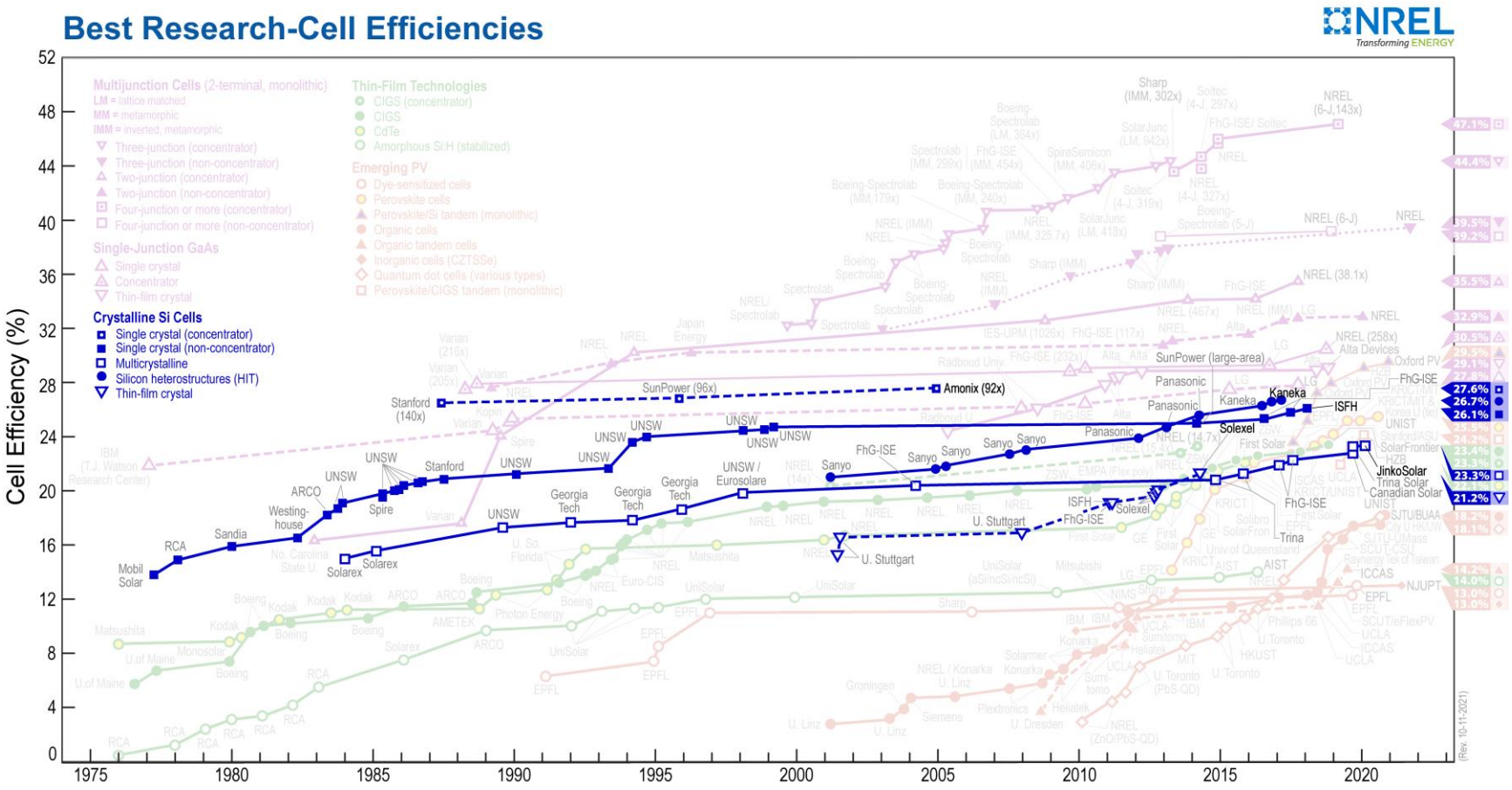
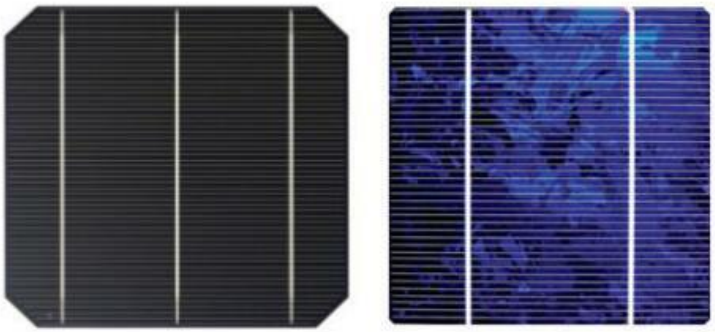


Source: NREL

Overview of Silicon PV

CRYSTALLINE AND MULTICRYSTALLINE SILICON

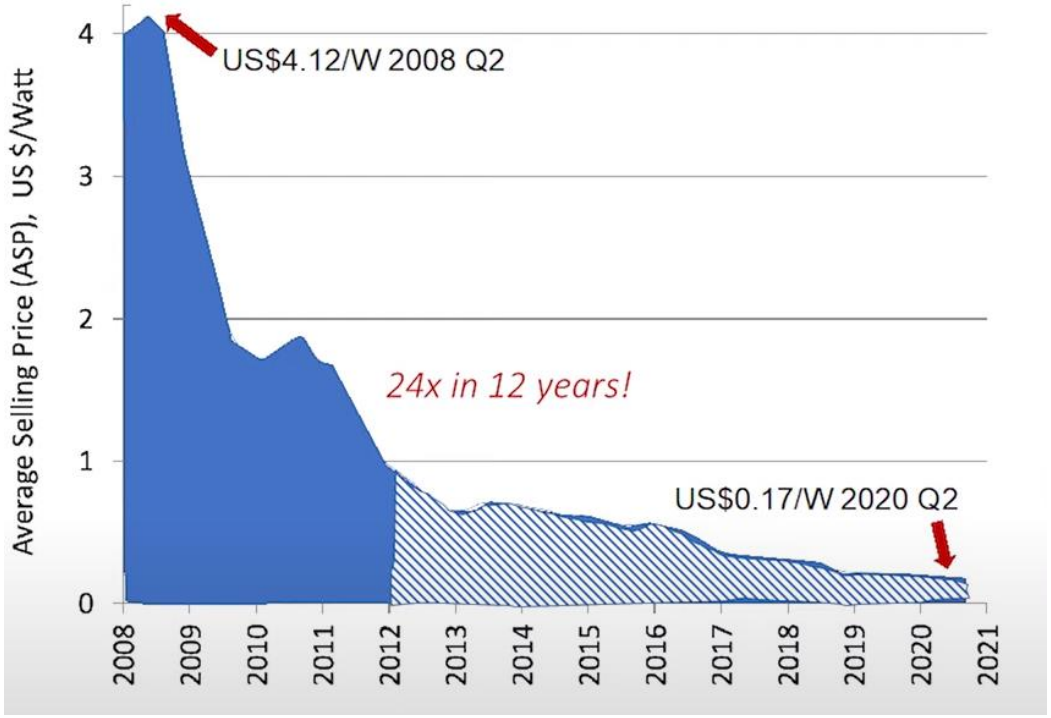
- Silicon solar cells make up >90% of the global PV production
- Various forms of silicon used
  - Monocrystalline, multicrystalline, cast-mono
- Now reaching cell efficiencies of up to 26.7% and module efficiency up to 24.4% (mono) and 20.4% (multi)
- Well-established technology but there is still room for improvement!



Overview of Silicon PV

DECADES OF PROGRESS

- Silicon PV has experienced decades of technological growth and cost reduction
- This has led to dramatic capacity growth



Source: Solar cells take on climate change, M. Green

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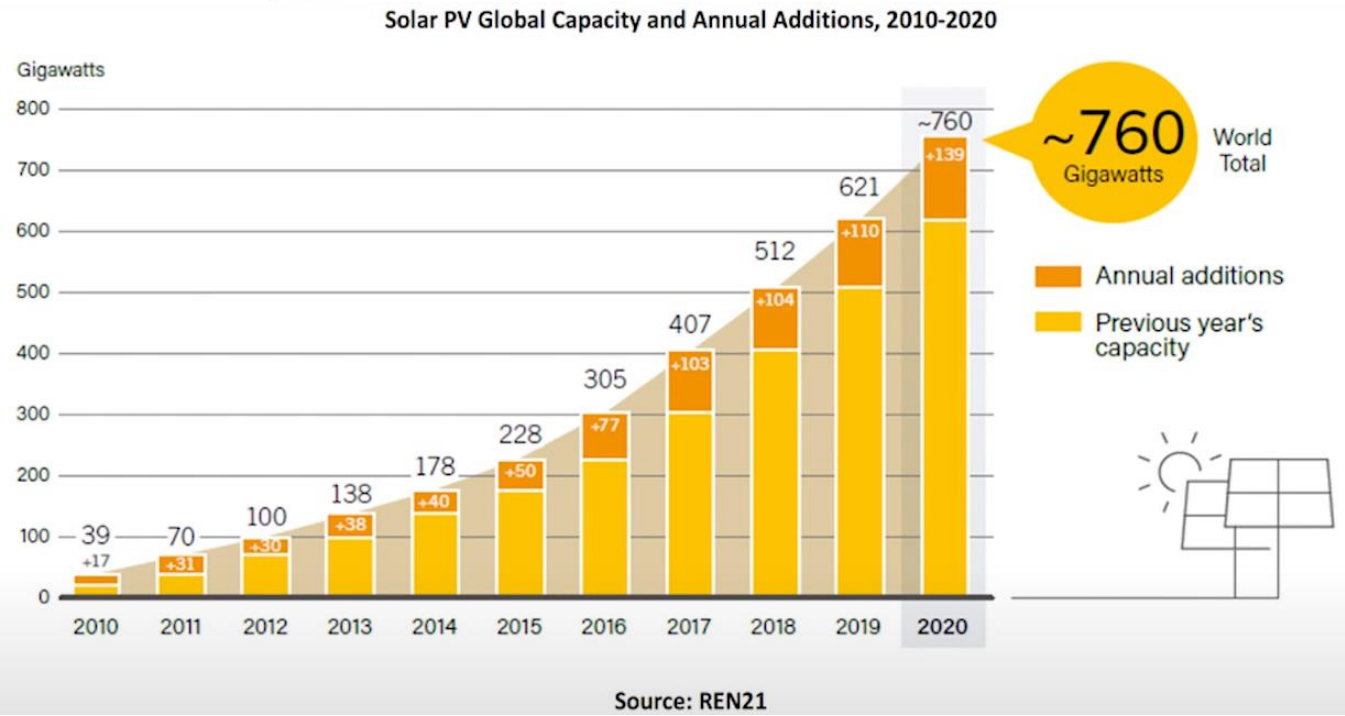

Overview of Silicon PV

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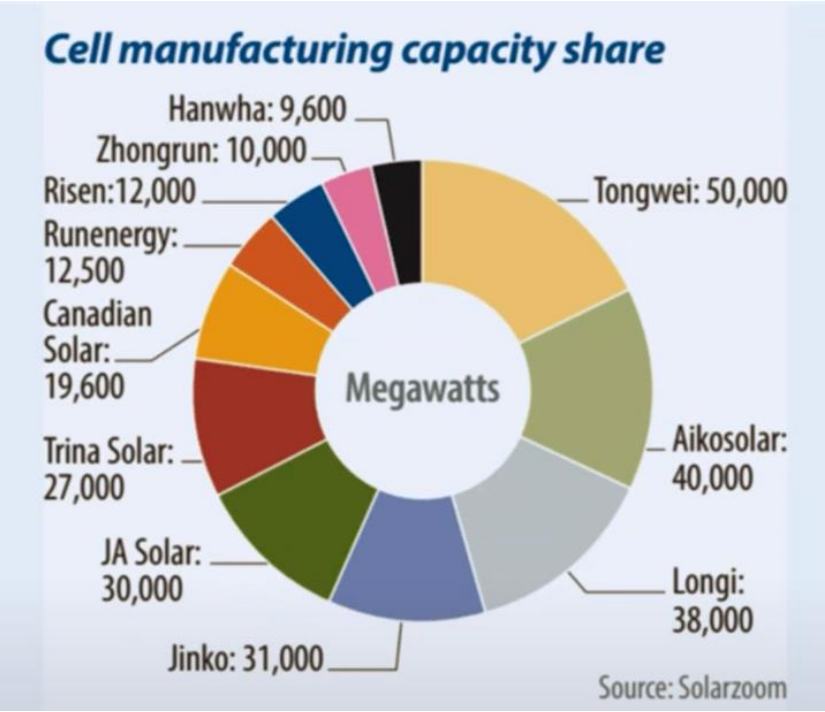

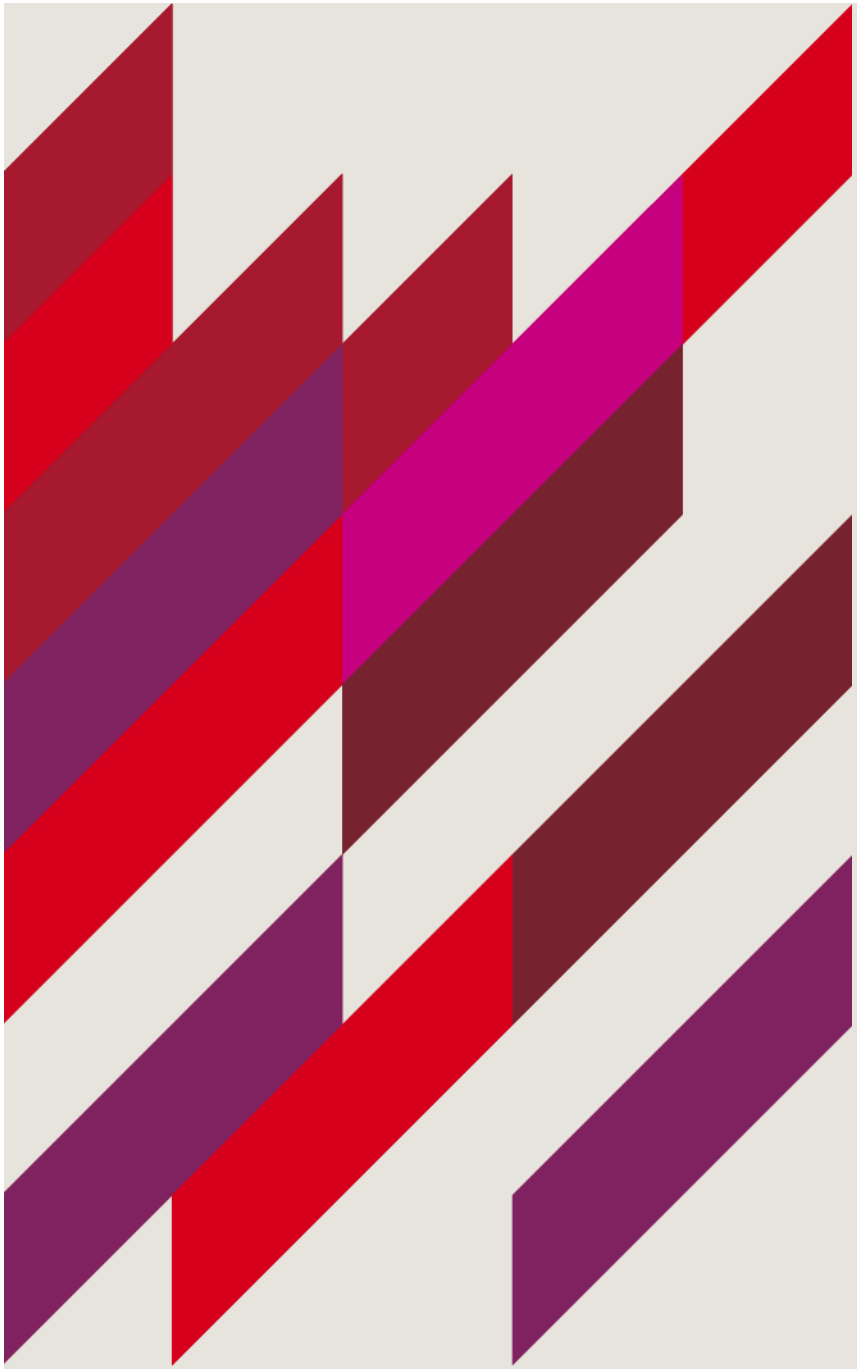

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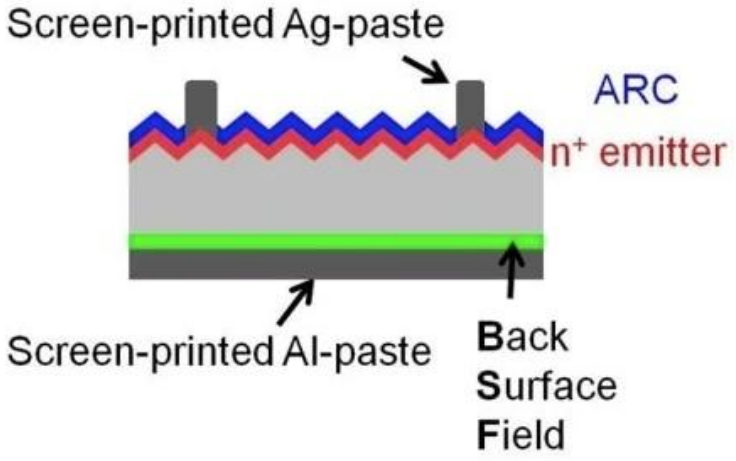
Recent Advances

Recent Advances

DEVICE STRUCTURE

- For decades the aluminium back-surface field (Al-BSF) structure dominated the industry
- In the last 5 years, passivated emitter and rear cell (PERC) technology has taken over
- The PERC structure adds rear passivation layer with periodic metal contacts, rather than a fully contacted rear
  - Higher efficiencies
  - Bifacial compatible



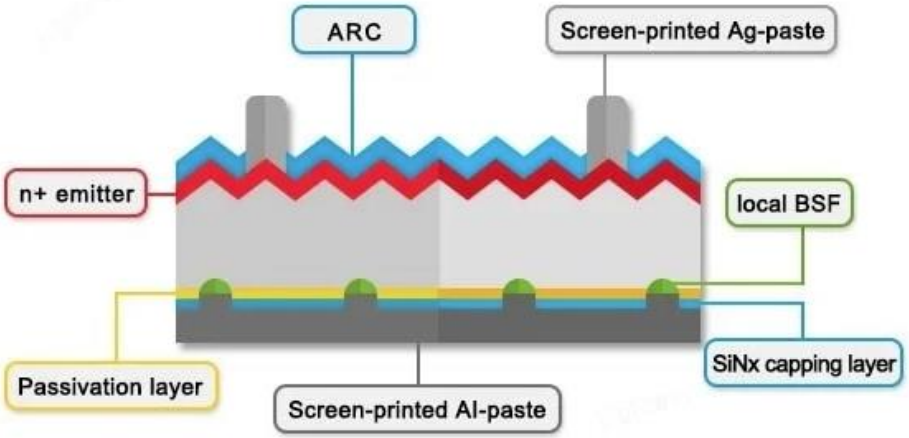


Image Source: ISFH & ENF Solar

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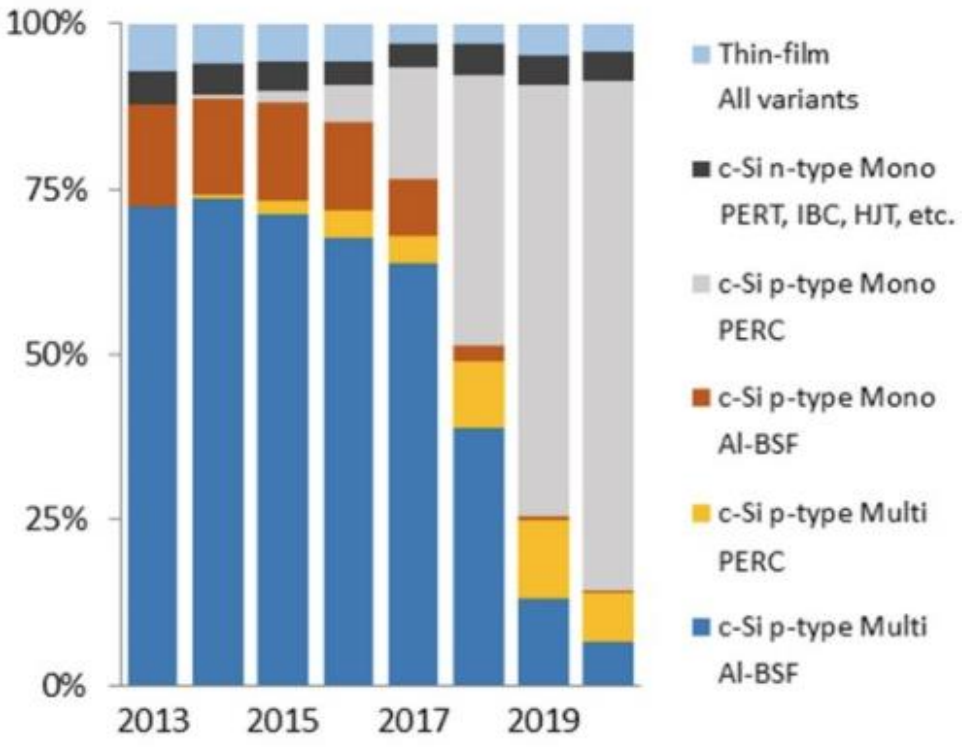

Source: PVTech – PV CellTech 2020

Recent Advances

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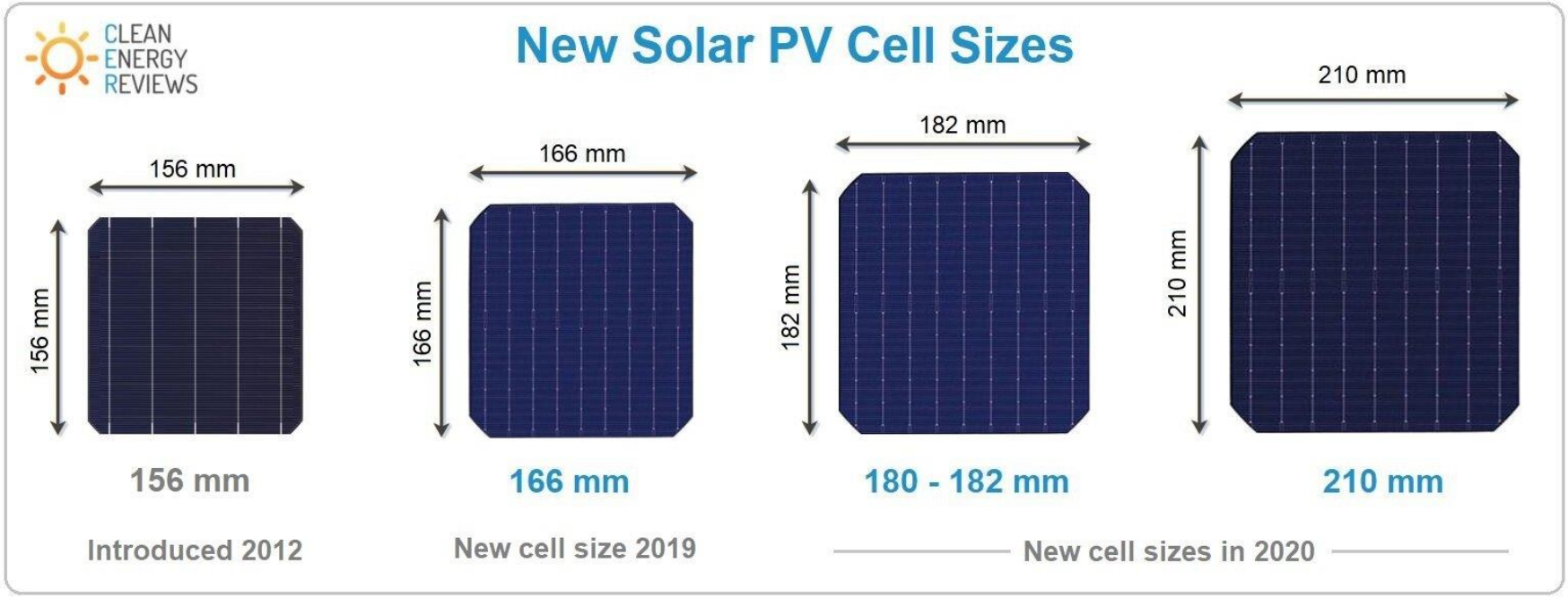
SILICON WAFERS

- Silicon wafer fabrication has improved in terms of material quality, waste and size.
  - Improved and more cost-effective ingot production
  - Diamond wire sawing
  - Gallium doping



Recent Advances

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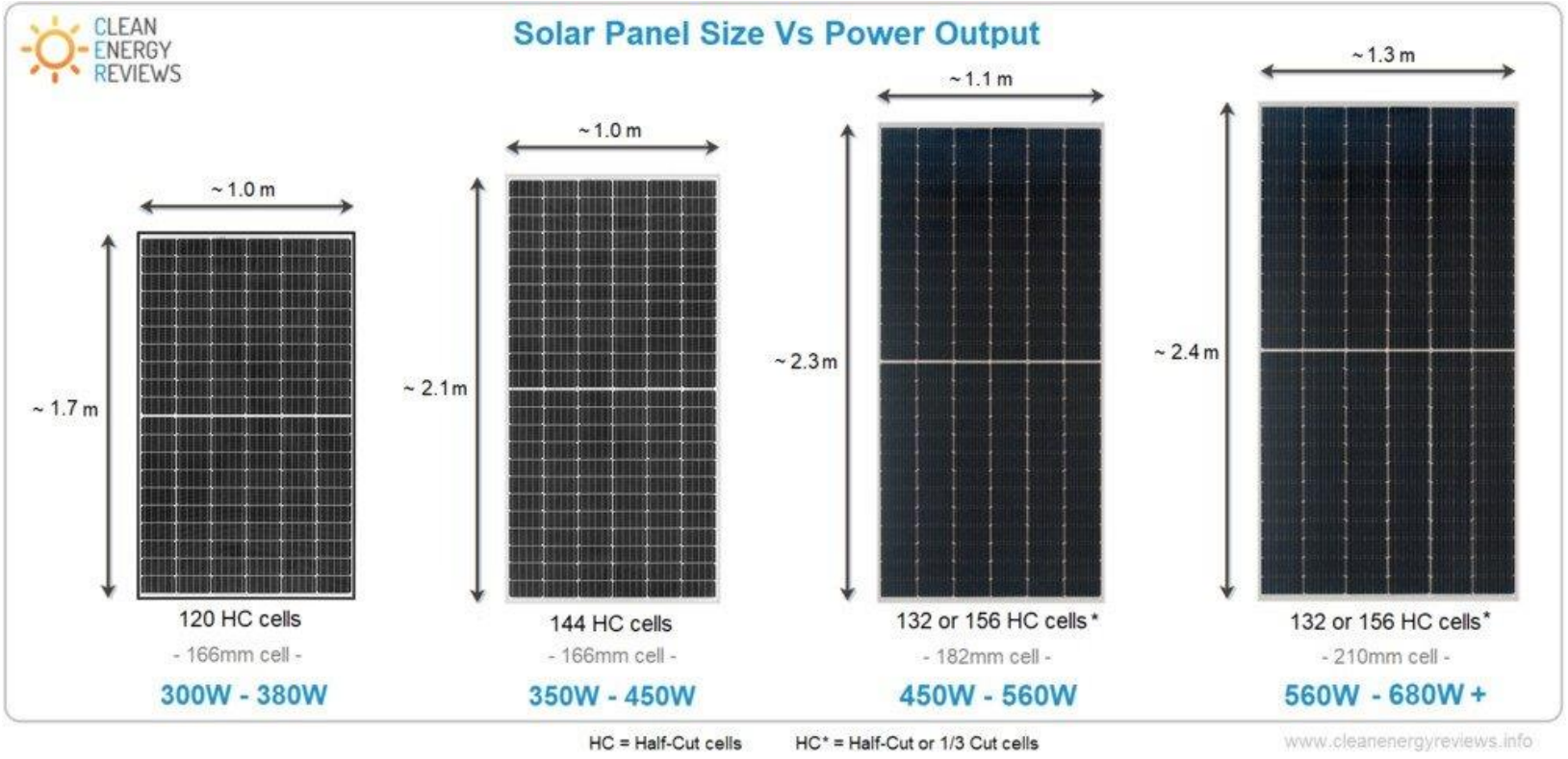
MODULES

- Modules are getting bigger and more efficient
  - Thinner contacts (less shading)
  - Half cells and shingling
  - Higher density of cells
  - Increased uptake of bifacial



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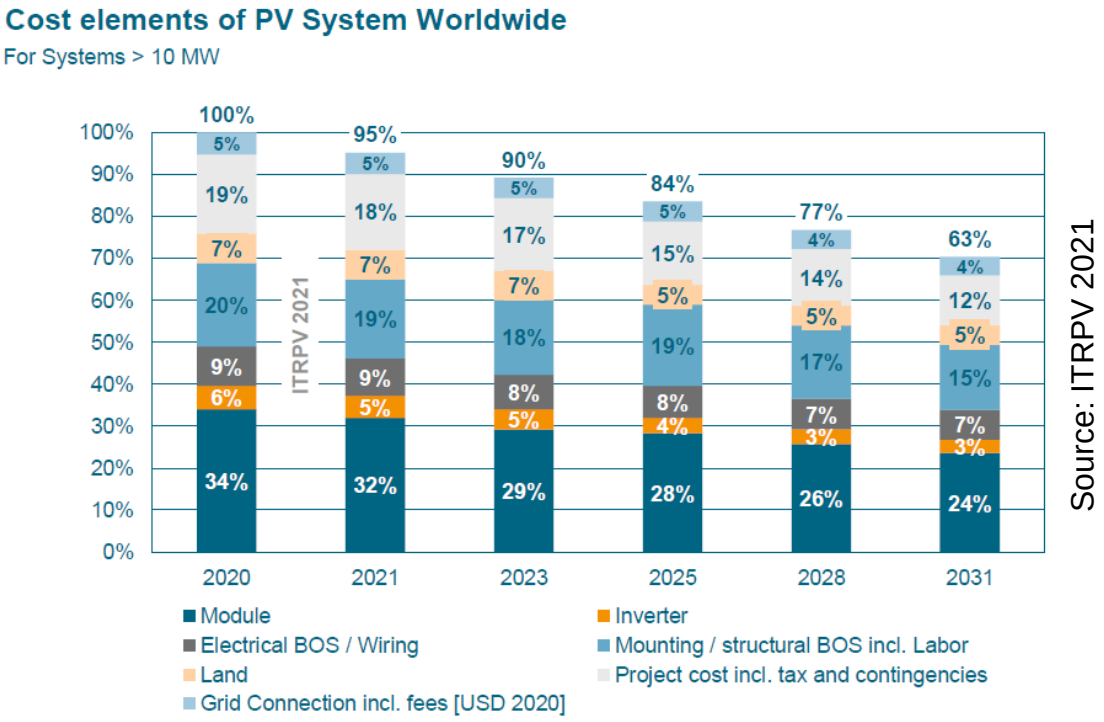
Enduring Challenges

Enduring Challenges

ACCELERATING UPTAKE

- Faster uptake of clean energy sources is needed in order to minimise climate change impacts
- Achieved through further reduction in cost/watt.
  - Increase efficiency - Reduce the cost of manufacturing
  - Use lower cost materials - Increase manufacturing yield



Source: ITRPV 2021

Enduring Challenges

ACCELERATING UPTAKE

- Simultaneously we can increase demand:
  - More aesthetic modules
  - Diversification of products and applications
    - Building integrated PV, Indoor PV etc.

Source: Mashriq Energy

Source: GAF Energy

Source: Tesla

Enduring Challenges

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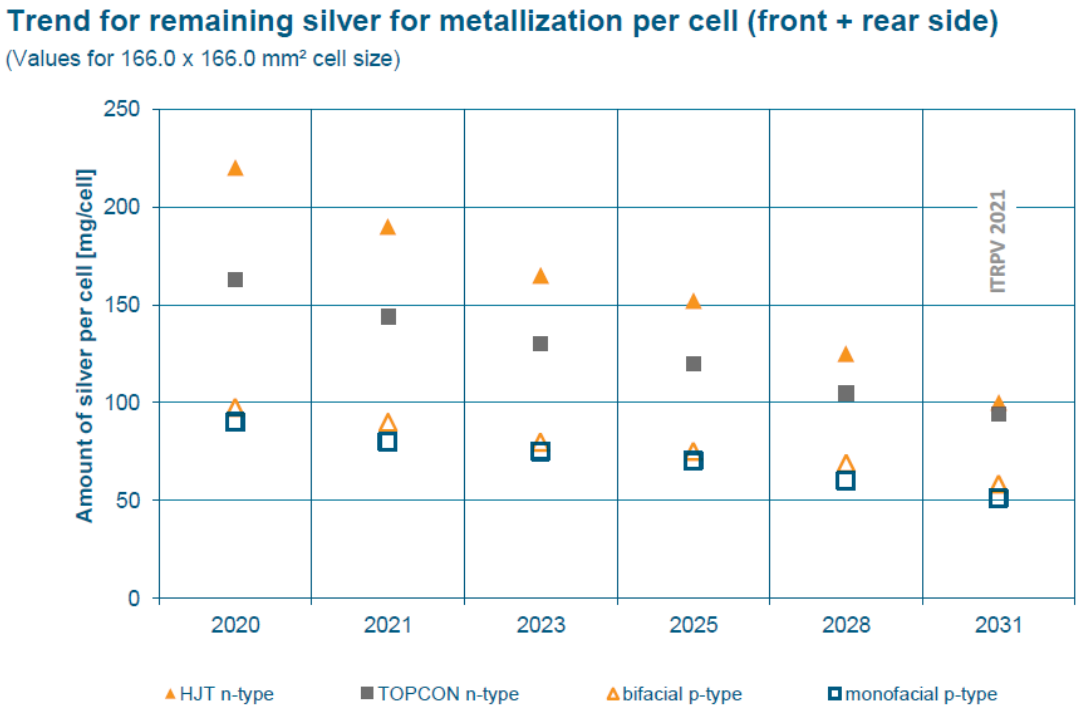
SUSTAINABILITY

- We must consider the full life-cycle of any solar product
- Optimise materials used to avoid harmful waste or depletion of supply
  - Reduce/eliminate usage of silver
  - Eliminate lead usage



Source: ITRPV 2021

Enduring Challenges

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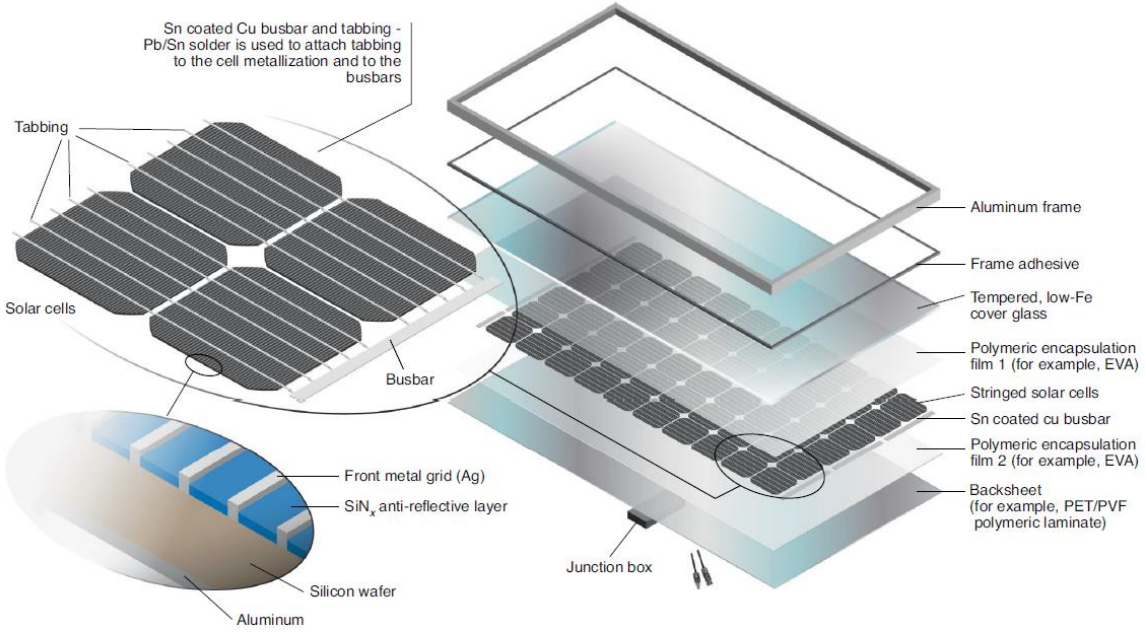
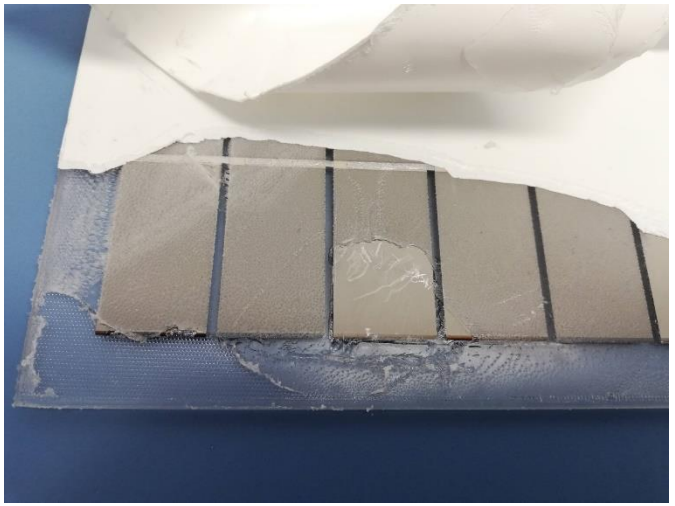
SUSTAINABILITY

- Improve recycling capabilities and policies for a circular economy
- Material separation is a key challenge
  - Currently uses a combination of mechanical, thermal and chemical processes
  - Separation of the encapsulant is particularly inefficient



Source: https://doi.org/10.1038/s41560-020-0645-2

Our team has a patent in progress here!



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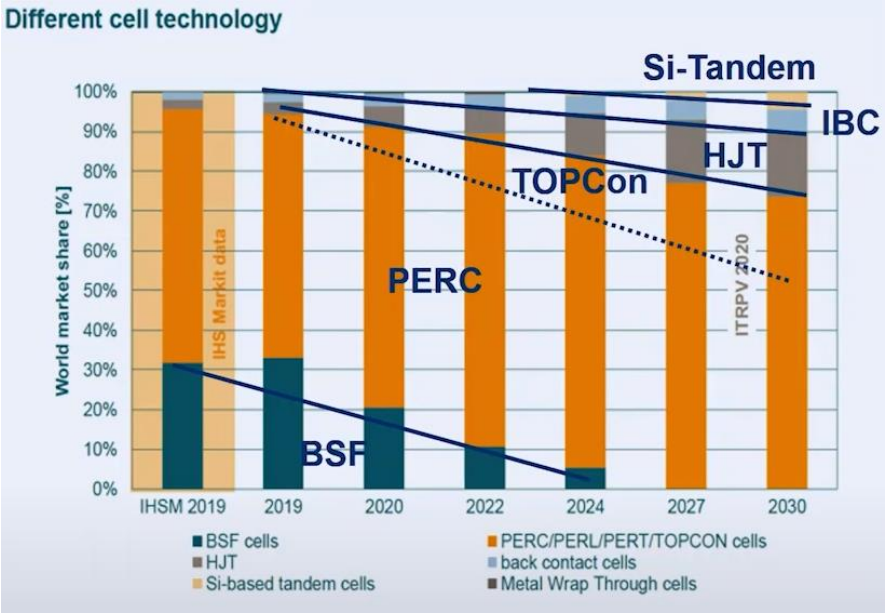
What's Next?

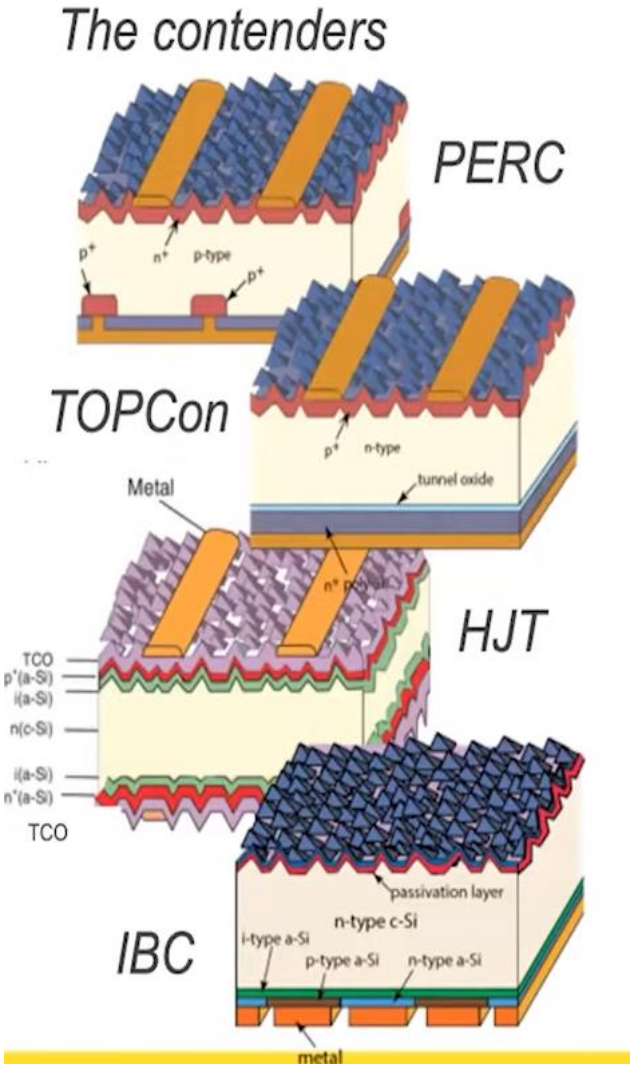
What's Next

ANTICIPATED DEVELOPMENTS

- In the near future there is competition between emerging technology currently being adopted by industry
- Bifacial modules are also expected to dominate the market



Source: ITRPV / Recent trends in photovoltaics, M. Green



Source: Solar Photovoltaics: Power Source for the future, M. Green

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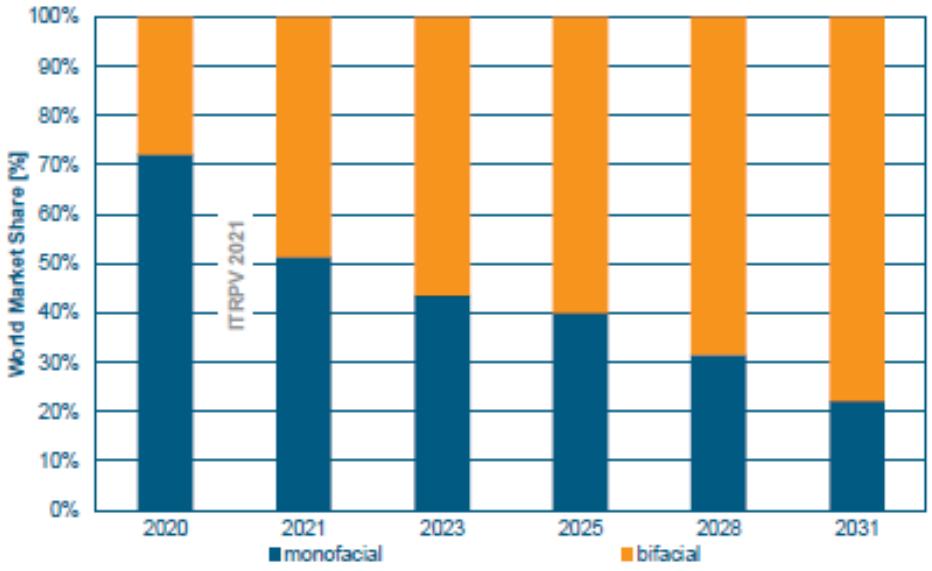

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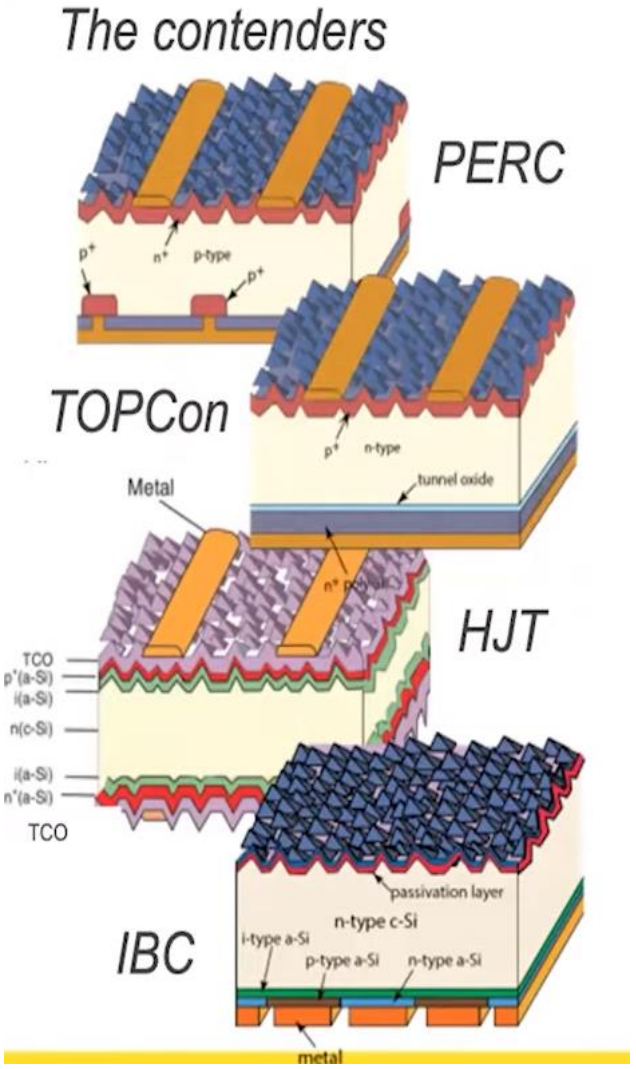

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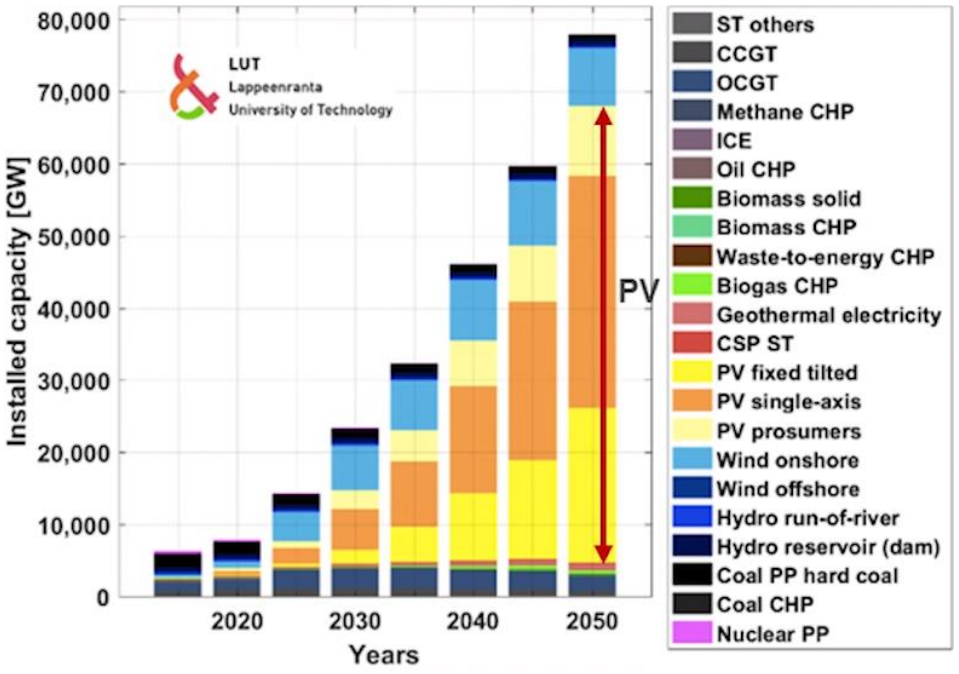

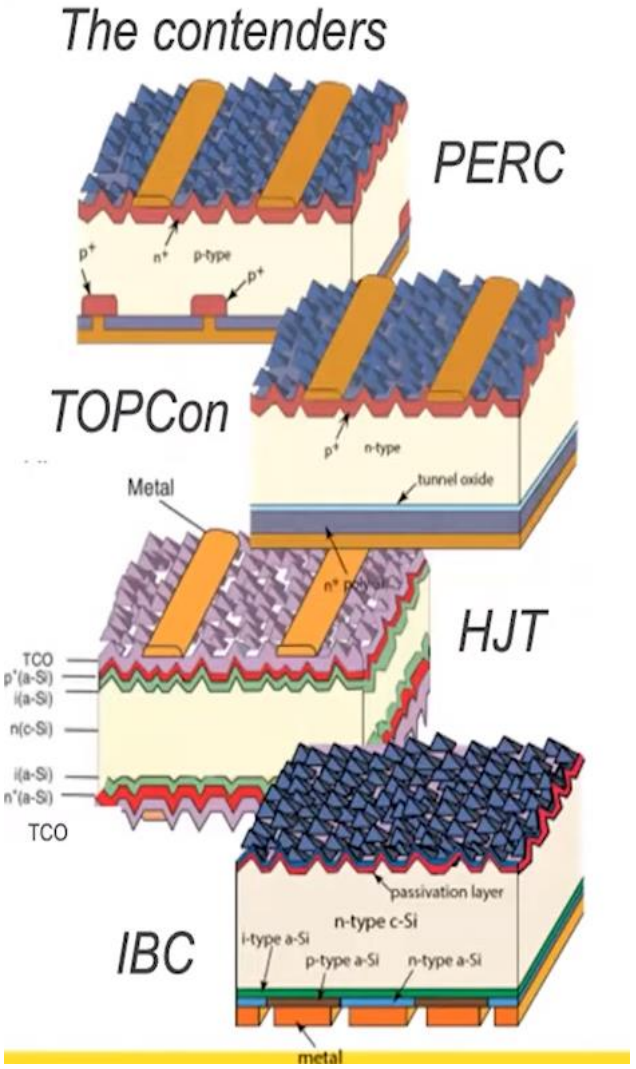

Source: Solar Photovoltaics: Power Source for the future, M. Green

What's Next

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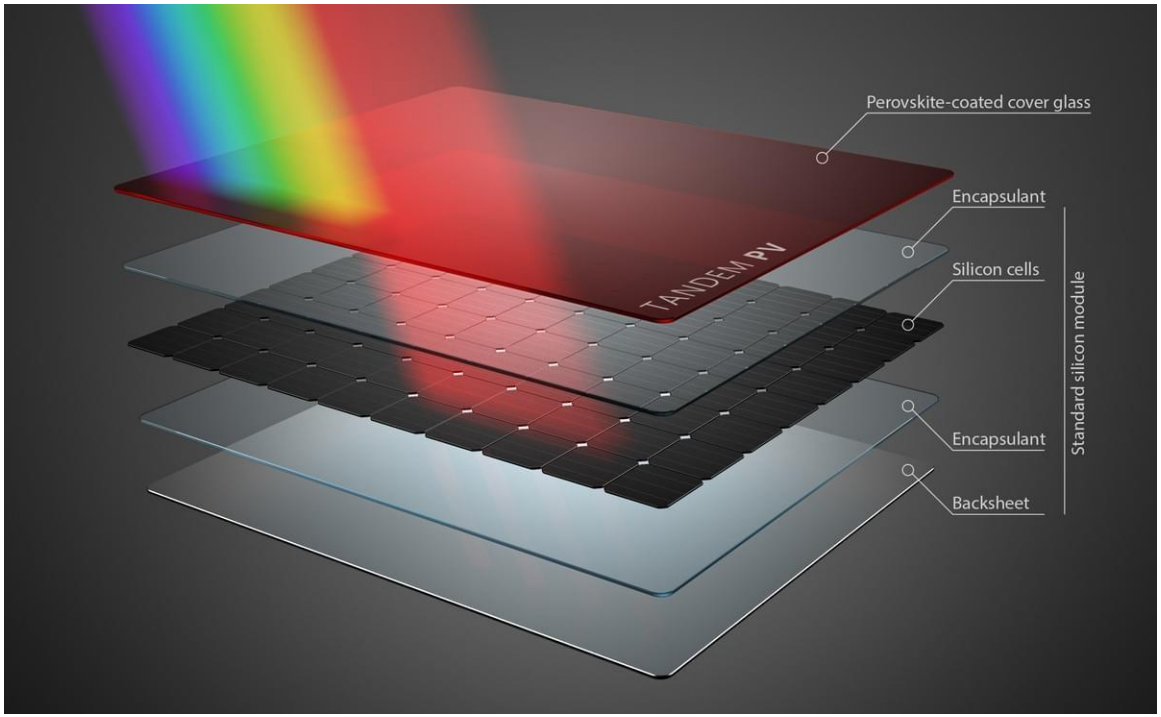
ANTICIPATED DEVELOPMENTS

- Further down the line we will need to go beyond single-junction silicon cells

  - Silicon/perovskite tandem cells

  -All thin-film multi-junction cells



Source: TandemPV

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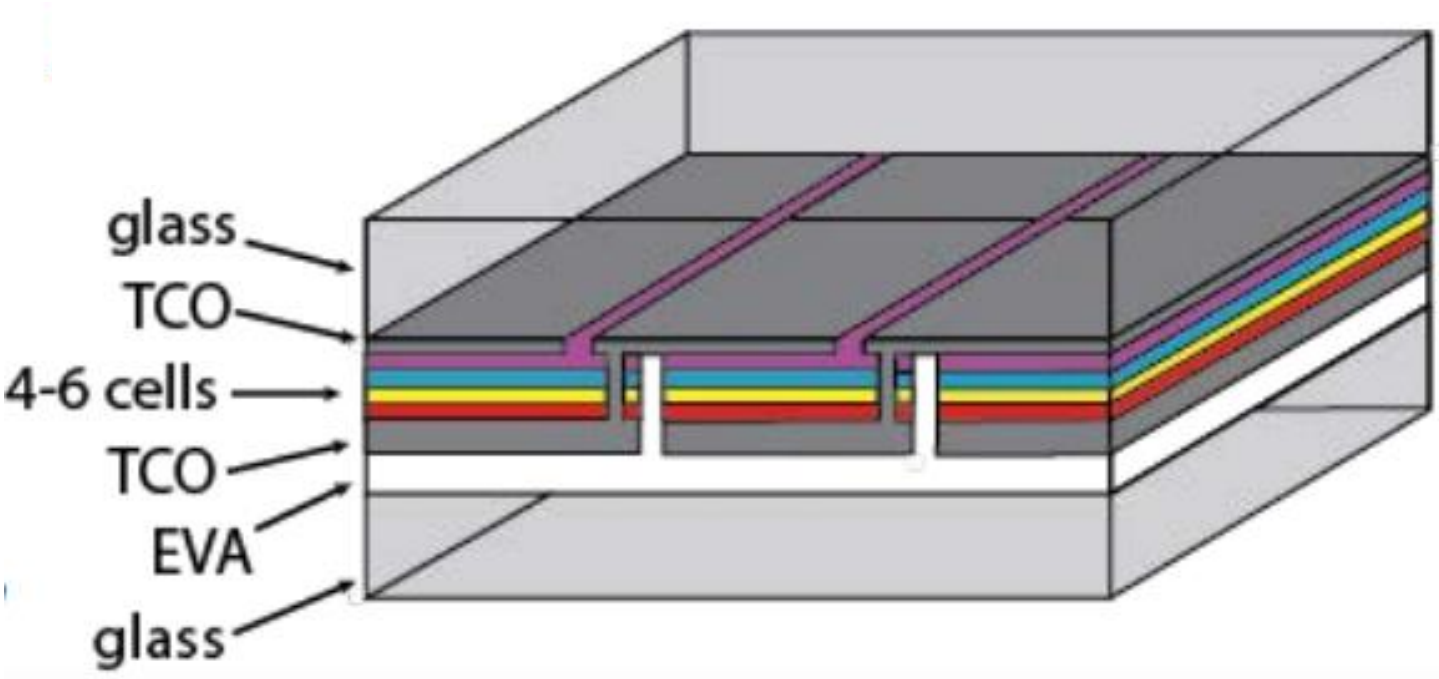

Source: Solar Photovoltaics: Power Source for the future, M. Green

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Thank you

Any Questions?

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ARENA

Australian Government
Australian Renewable Energy Agency

UNSW SYDNEY