Pathway Towards Low-Cost, High-Efficiency Solar Cells by Dynamic Hydride Vapor Phase Epitaxy

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Renewable Energy

https://youtu.be/a_gujmtlbzA

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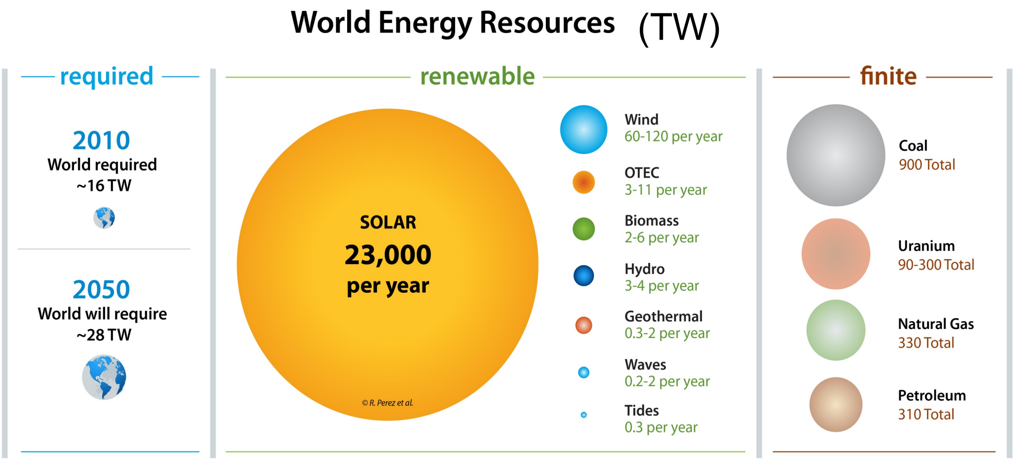
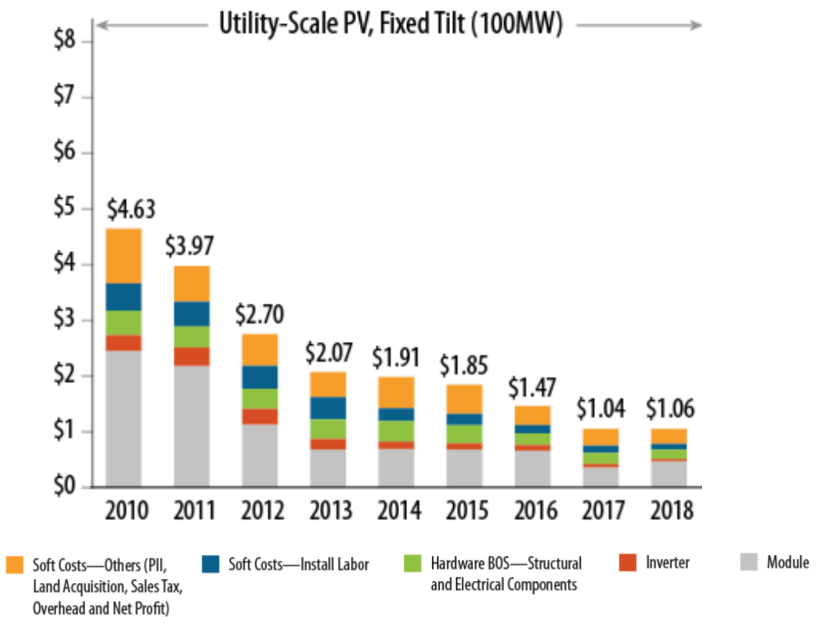
Introduction: Why Solar?



23,000 TW are incident on the earth from the sun per year – three orders of magnitude more than the projected global consumption for 2050



Meanwhile, the cost of solar panels has substantially decreased in the last decade

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III-V Materials for Solar Applications

	Silicon	vs.	III-Vs
Power conversion efficiency	18-21%		**26-34%**
Power output per weight	260 W/kg		**1100 W/kg**
Power output per area	200 W/m^2		**300 W/m^2**
Flexibility	Rigid		**Rigid or flexible**
Market share	**95%**		<1%
Cost	**<$1/W**		$61/W


Source: John Geisz


Source: NASA


Source: TITAN

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Solar cells can be made from a variety of materials including silicon and III-Vs. III-V materials have higher solar cell performance than silicon, but are more expensive. If their cost could be reduced, III-Vs could enable many applications that are difficult now.

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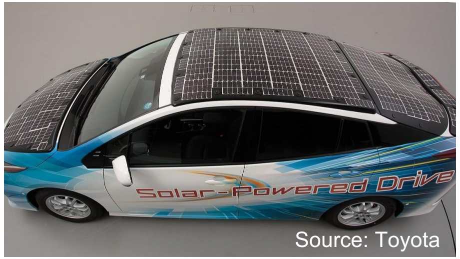
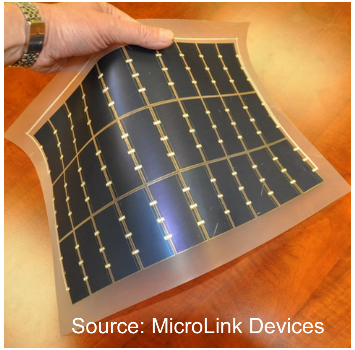
Enabling Applications



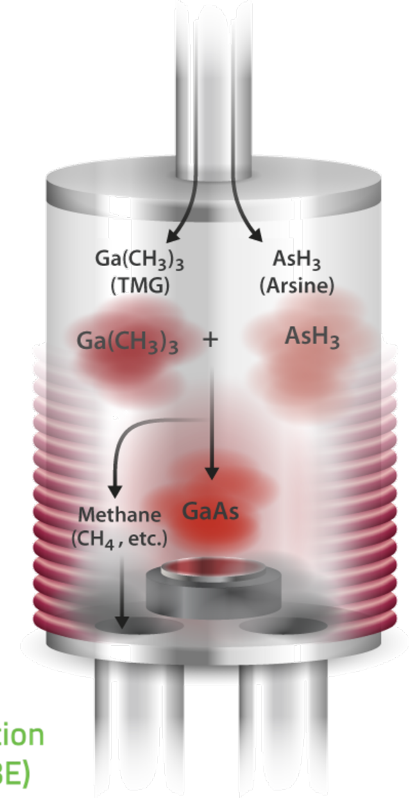
Source: Toyota


Source: MicroLink Devices

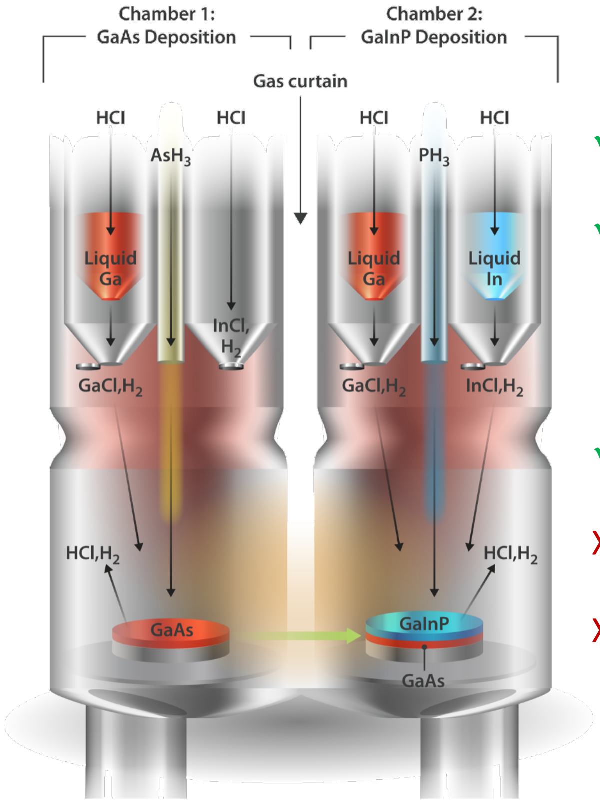
III-V Epitaxy Methods

The Incumbent Method (Organometallic Vapor Phase Epitaxy)

- ✓ Reliably produces high-quality, complex solar cells
- X Low growth rates typically used in industry
- X Expensive organometallic precursors ($1/g for the Ga precursor)



The Alternative Method (Dynamic Hydride Vapor Phase Epitaxy)



- ✓ Fast growth rates > 0.5 mm/h
- ✓ Lower-cost precursors ($0.21/g for the elemental Ga precursor)
- ✓ More efficient use of precursors
- X Only research scale so far
- X Uses flammable hydrogen gas

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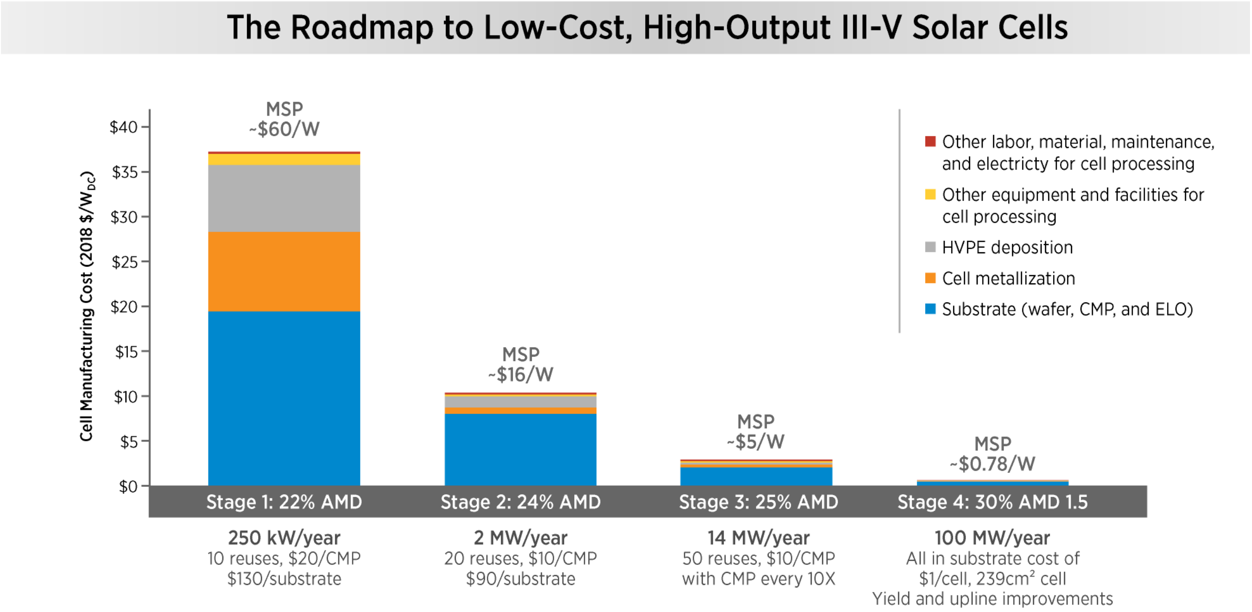
Objective

Our objective is to maintain III-V solar cells with very high efficiency while exploring methods to reduce the cost

This poster discusses the enabling role of nitrogen carrier gas to reduce HVPE deposition costs



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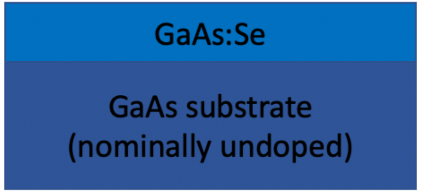
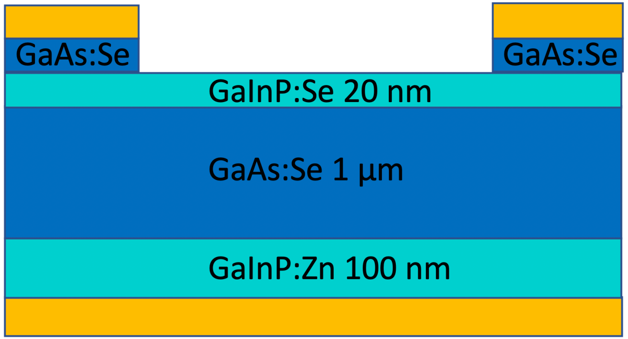
Methods: D-HVPE Growth

We grew GaAs test structures to determine the growth rate with a **nitrogen carrier gas, which is safer and cheaper** than hydrogen carrier gas that is typically used

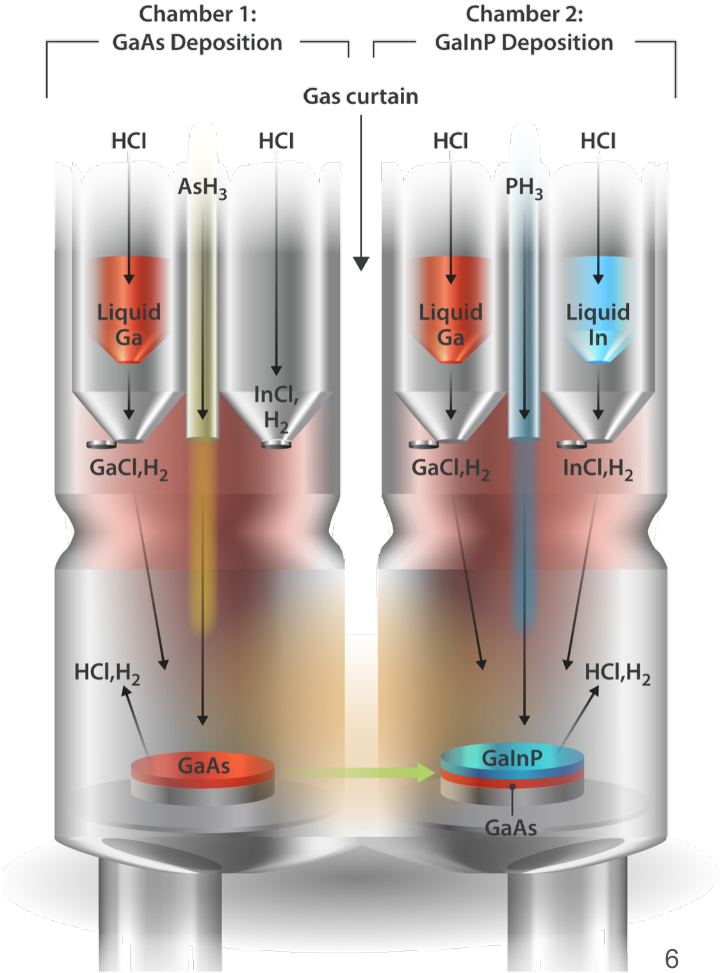
We then developed solar cells to confirm that they still maintain high efficiency at high growth rates with nitrogen



1) Test structure for growth rate calibration



2) Solar cell growth



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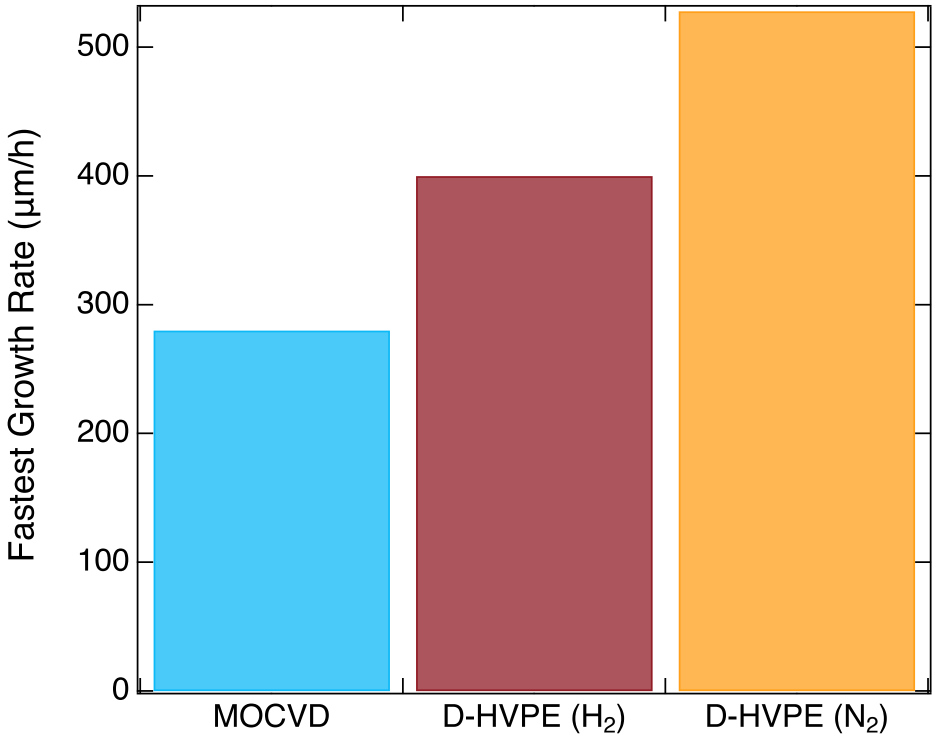
Results: Growth Rate Enhancement

We used the maximum AsH_3 flow and increased the GaCl flow to compare the influence of carrier gas on growth rate

We observed a growth rate of **528 μm/h using nitrogen carrier gas** and 400 μm/h using hydrogen carrier gas

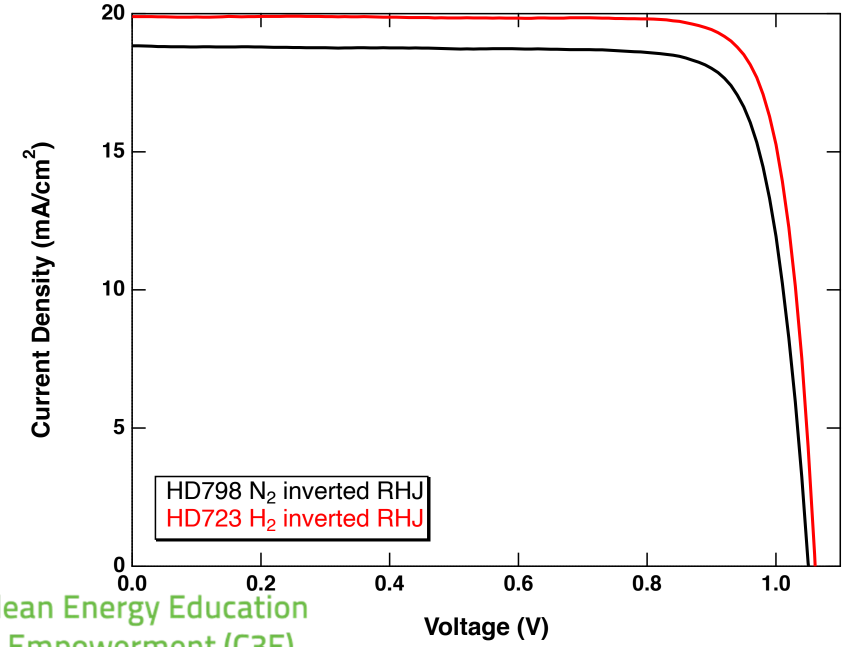
This growth rate enhancement could improve throughput in industrial-scale reactors, while utilizing a carrier gas that is **cheaper and safer** than the current standard

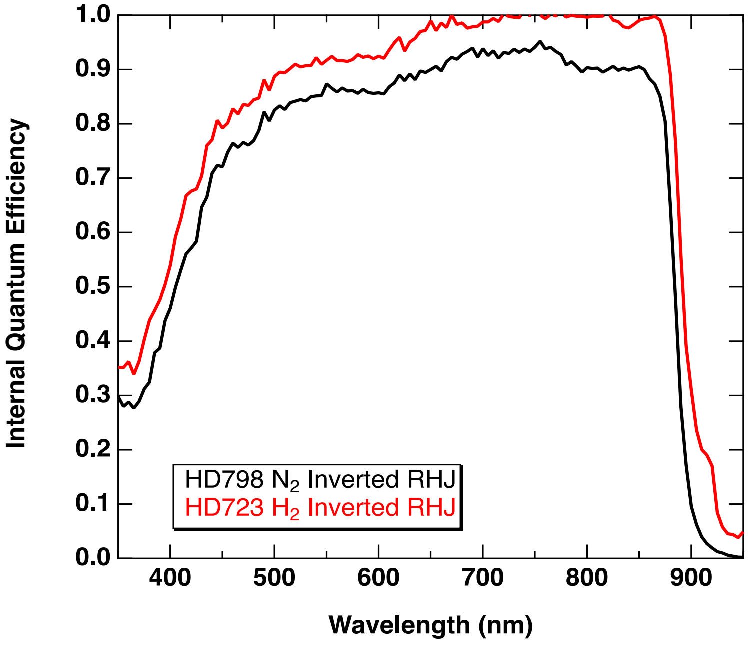


Results: Solar Cell Performance

Estimated **24% power conversion efficiency** with an antireflection coating at a growth rate of 30 μm/h

The open circuit voltage (which predicts material quality) is within 20 mV of the hydrogen baseline with almost no optimization. The difference in the short-circuit current density is due to a difference in layer thickness.





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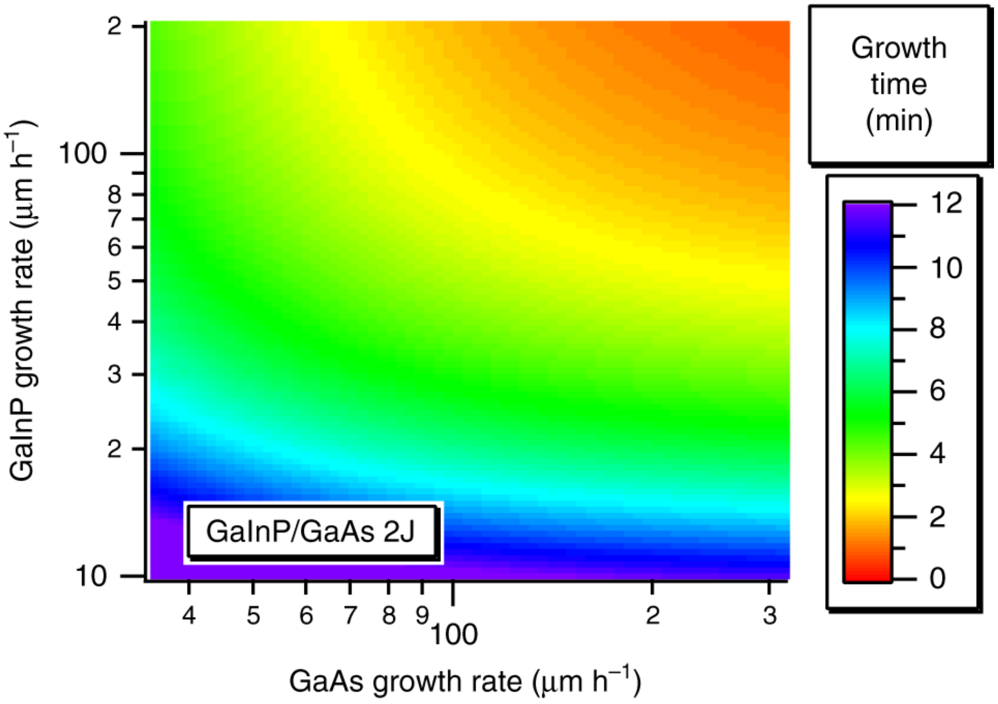
Conclusions

Higher growth rate can lead to lower time to grow a single-junction or multijunction III-V solar cell

We found that using nitrogen carrier gas improves the growth rate compared to hydrogen carrier gas, and has additional benefits such as being cheaper and safer

Improvements in throughput decrease the cost associated with epitaxy



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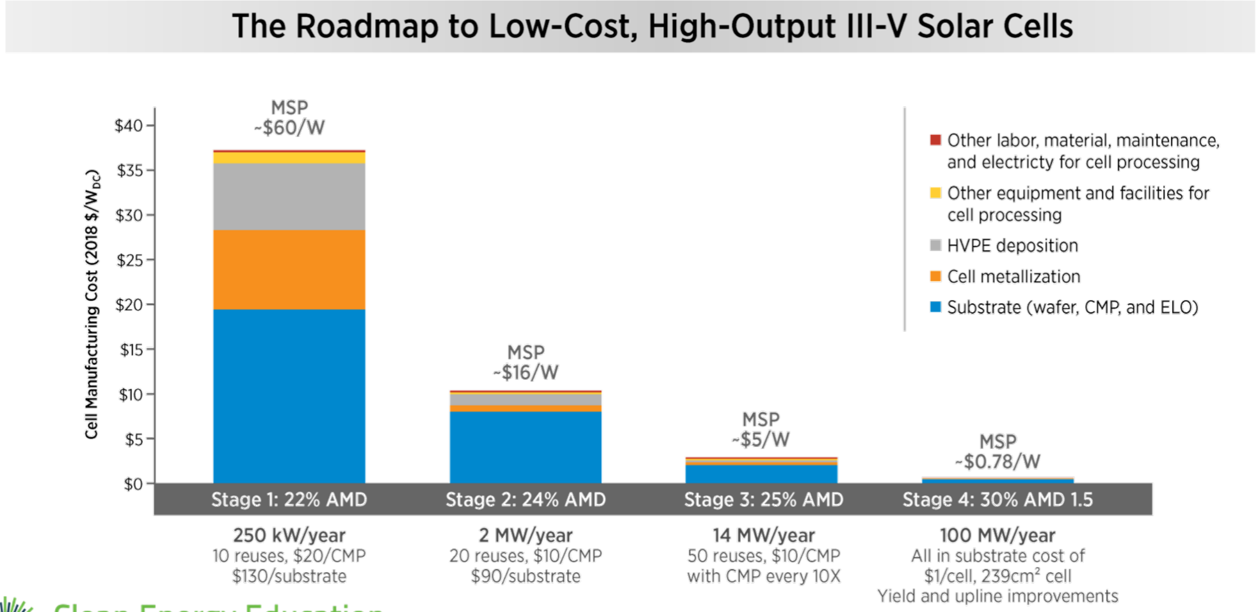
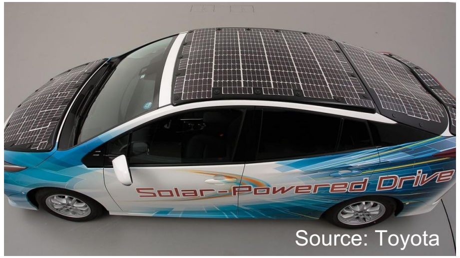
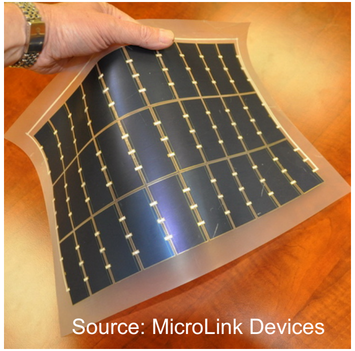
Impact

This work combined with continued scaling of D-HVPE reactors and techniques to reduce the cost of metallization and substrates will enable a pathway for III-V solar cells in many future technologies like **efficient, light-weight solar modules on cars** or **flexible and portable solar mats, tiles, and backpacks**





Source: Toyota


Source: MicroLink Devices

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Thank you!

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