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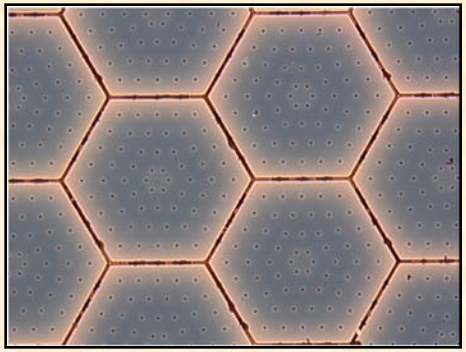

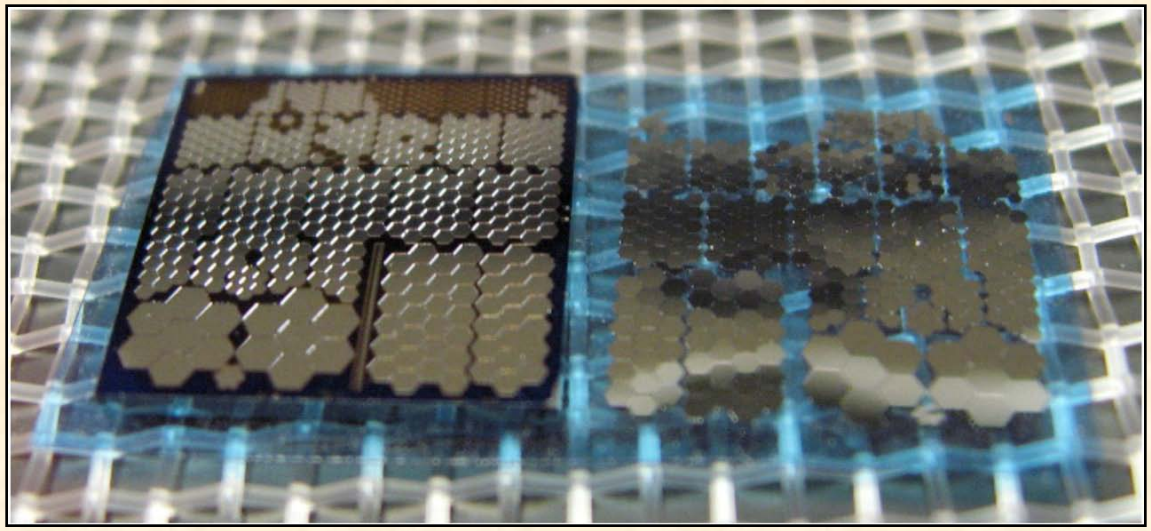

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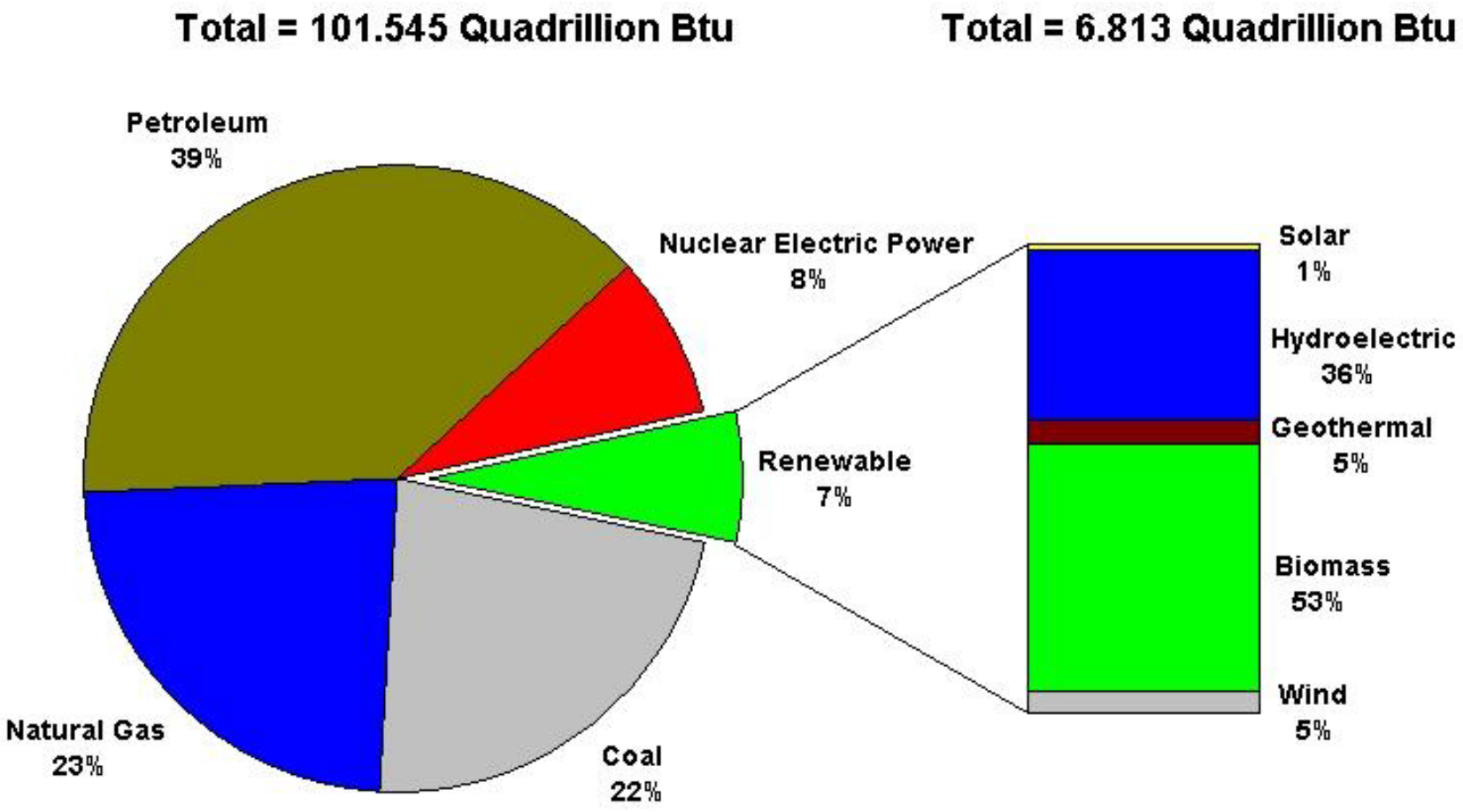
Microsystems Enabled Photovoltaics: A Path to the Widespread Harnessing of Solar Energy

"We are like tenant farmers chopping down the fence around our house for fuel when we should be using Nature's inexhaustible sources of energy – sun, wind, and tide. I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that."

– Thomas Edison to Henry Ford in 1931



Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels

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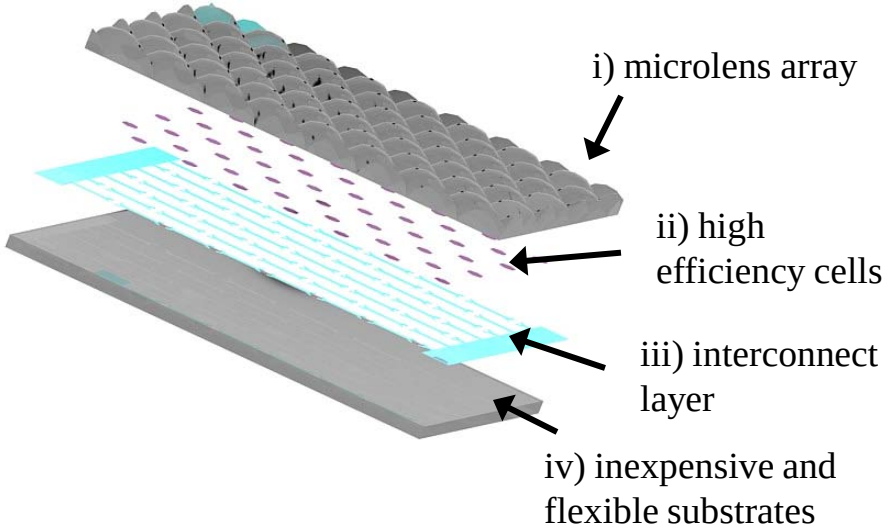
The Need for Solar Electricity

6 Boxes @ 3.3 TW each

- Emerging electrification of personal transport
- Decentralization of energy generation
- Growing concerns about atmospheric emissions from fossil fuel use
- Ever increasing global demand for electricity

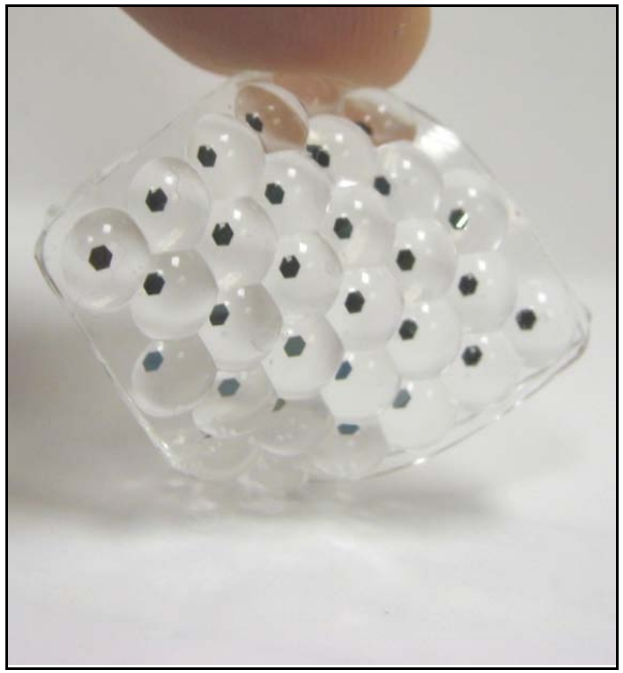
Source: Nathan Lewis, “Global Energy Perspective,” 2004

Making Solar Mainstream



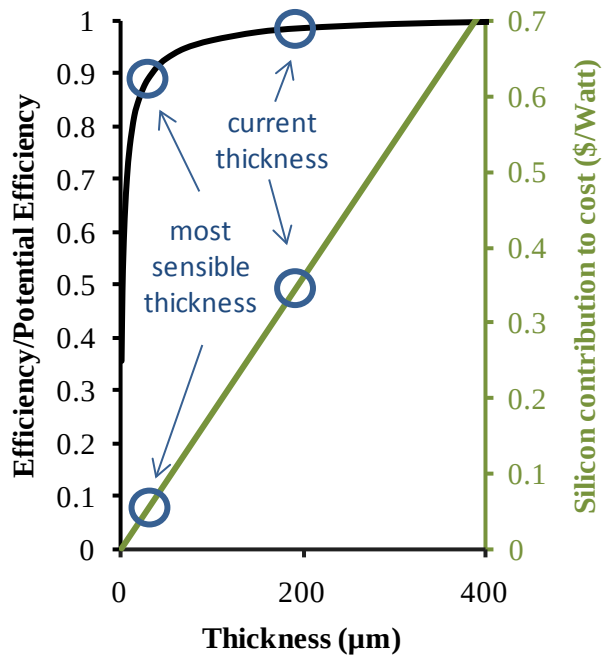
- Cheaper than all other forms of energy
- Easier and quick to install
- Safer, more reliable, and more durable than present-day grid power

Our Technology Vision



- High-concentration, sun-tracking MEPV for power utilities
- Low-concentration, flat-plate MEPV for horizontal rooftops
- Flexible, integrated MEPV for sloped rooftops, vehicles, gadgets, and the human body

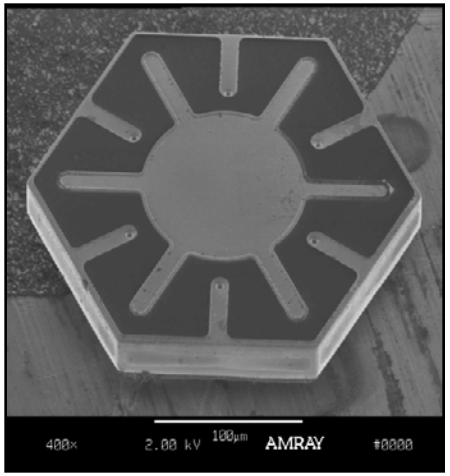
The Technical Requirements

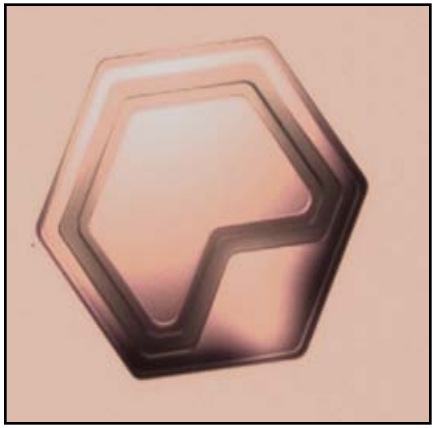


- Reducing the amount of necessary high-cost semiconductor material
- Developing highly efficient cells
- Achieving long-term durability and reliability
- Using low-cost packaging substrates
- Creating scalable high-speed assembly processes
- Establishing fast methods to install and wire the grid-connected circuitry

[redacted]

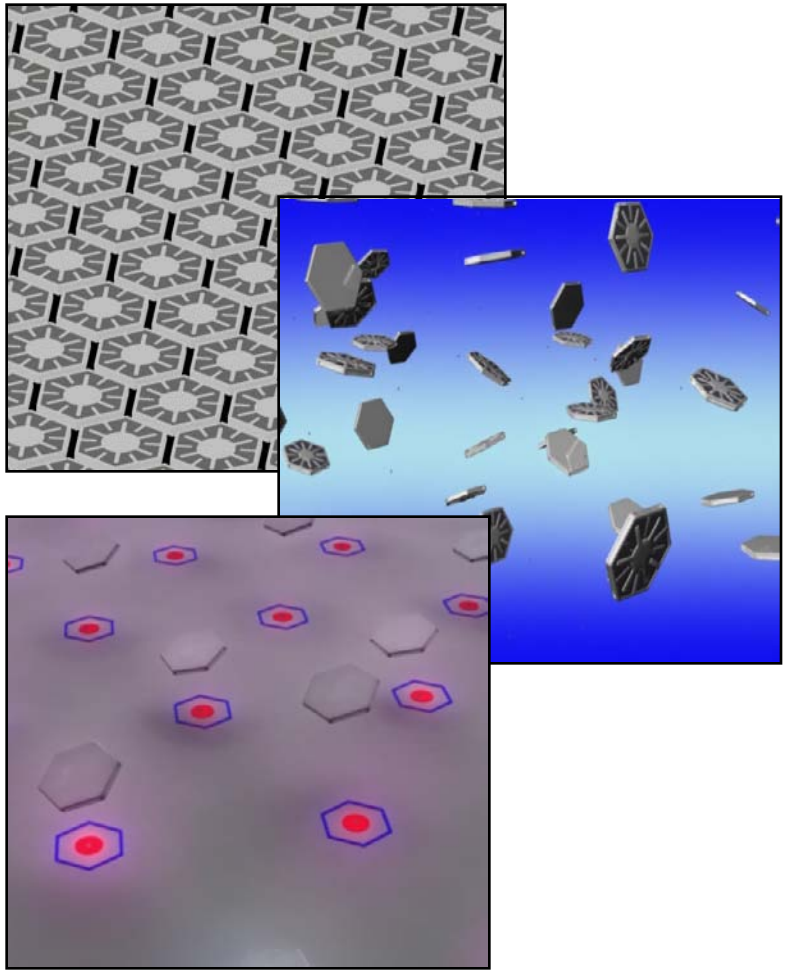
Going Small — Benefits at the Cell Level





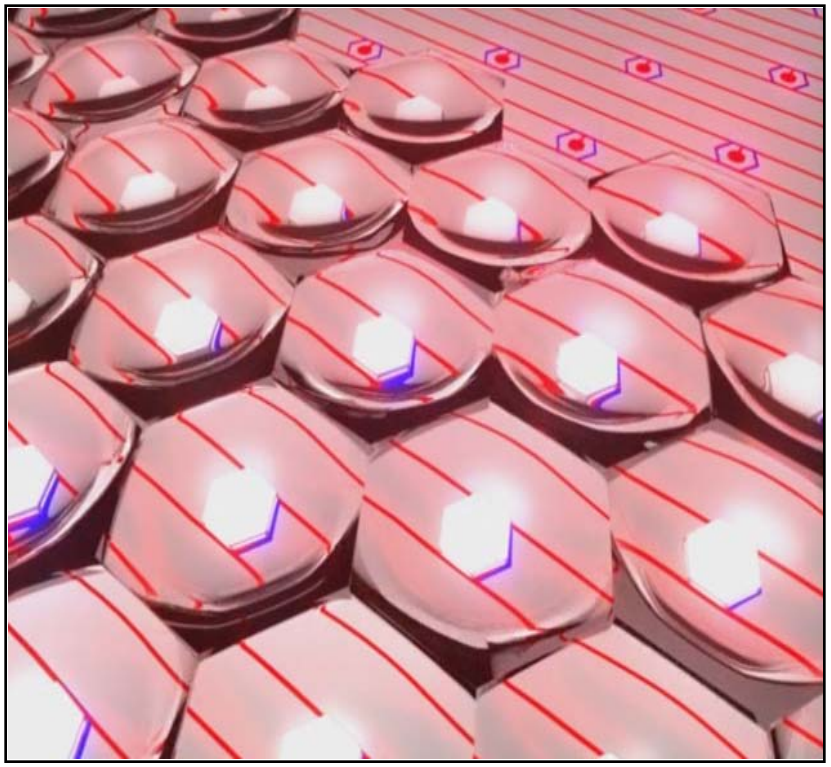
- Standard IC fabrication tools
- Better use of wafer area (i.e., lower edge die losses)
- Flexibility with respect to wafer size
- 10x less in semiconductor materials
- Improvements in carrier collection
- Potentially higher open circuit voltages
- Micro-optical concentration designs in flat plate configurations

Going Small — Manufacturing Benefits



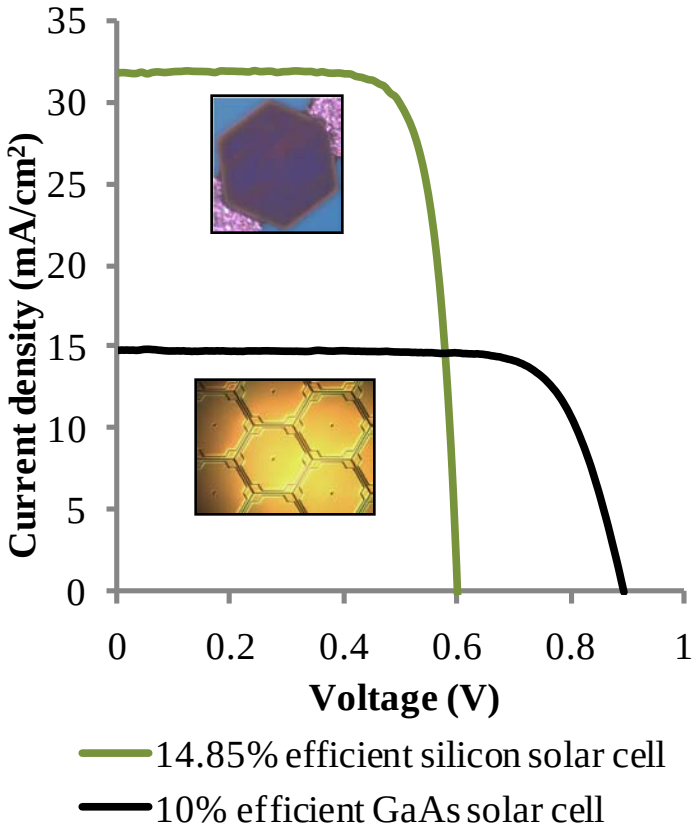
- Utilizes mature technology, tools, and techniques from microelectronics and microsystems
- All manufacturing steps done with micro-PV cells still attached to wafer
- Wafer can be reused
- Modules can be assembled using pick-and-place, tape-and-place, and self assembly methods

Going Small — Benefits at the System Level



- Can use refractive optics instead of Fresnel optics
- Thermal load management simplified
- Tolerances in sun tracking are higher
- Can be flush mounted at the point of use

Our Results to Date



- Have fabricated three solar cell designs:

-Silicon back-contacted radial pattern

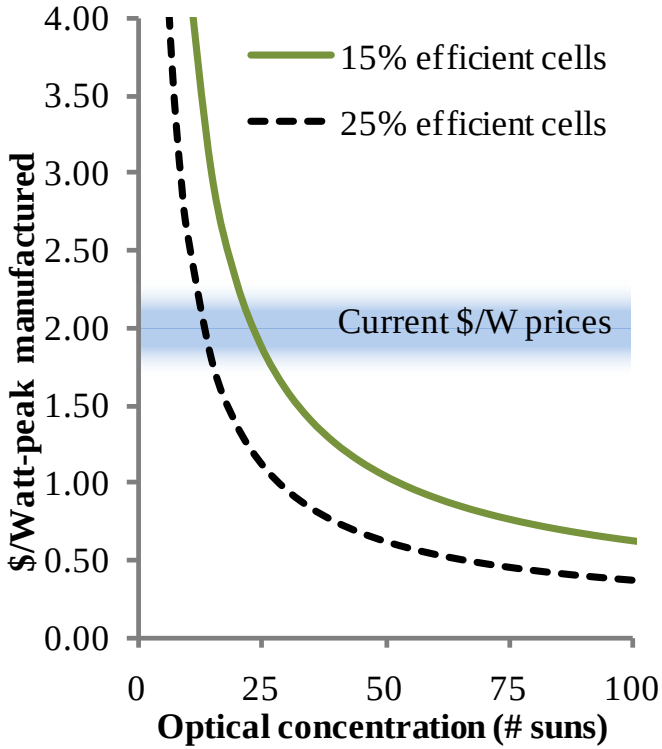
-Silicon back-contacted interdigitated format

- Ultrathin, single-junction GaAs cell with back contacts

- Have achieved 14.9% efficiency for 14 μm thick crystalline silicon cell

- Have achieved 10% efficiency for 3 μm thick GaAs cell

Concluding Observations



Assumptions
Solar Flux: 100mW/cm^2
Process Cost: $150/wafer
Wafer Diameter: 200 mm
Assembly Cost: $25/m^2
Cell Process Yield: 95%

- PV adoptions needs to grow at compounded annual growth rate of 40% per year to become a 40% contributor to US energy portfolio within one human generation
- This requires technology-cost breakthroughs in PV cells, assembly, installation, operation, and retirement
- If done well enough, PV will fill the shapes and curved contours of natural terrain, large manmade structures, vehicles, portable electronics, and the human body

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