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NCI Southwest

Where is my flying car? – Or
What thermodynamics can and cannot tell us about the future of solar

Friday, October 21, 2016

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Where is my flying car? - or

What thermodynamics can and cannot tell us about the future of solar

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Today’s presenter:
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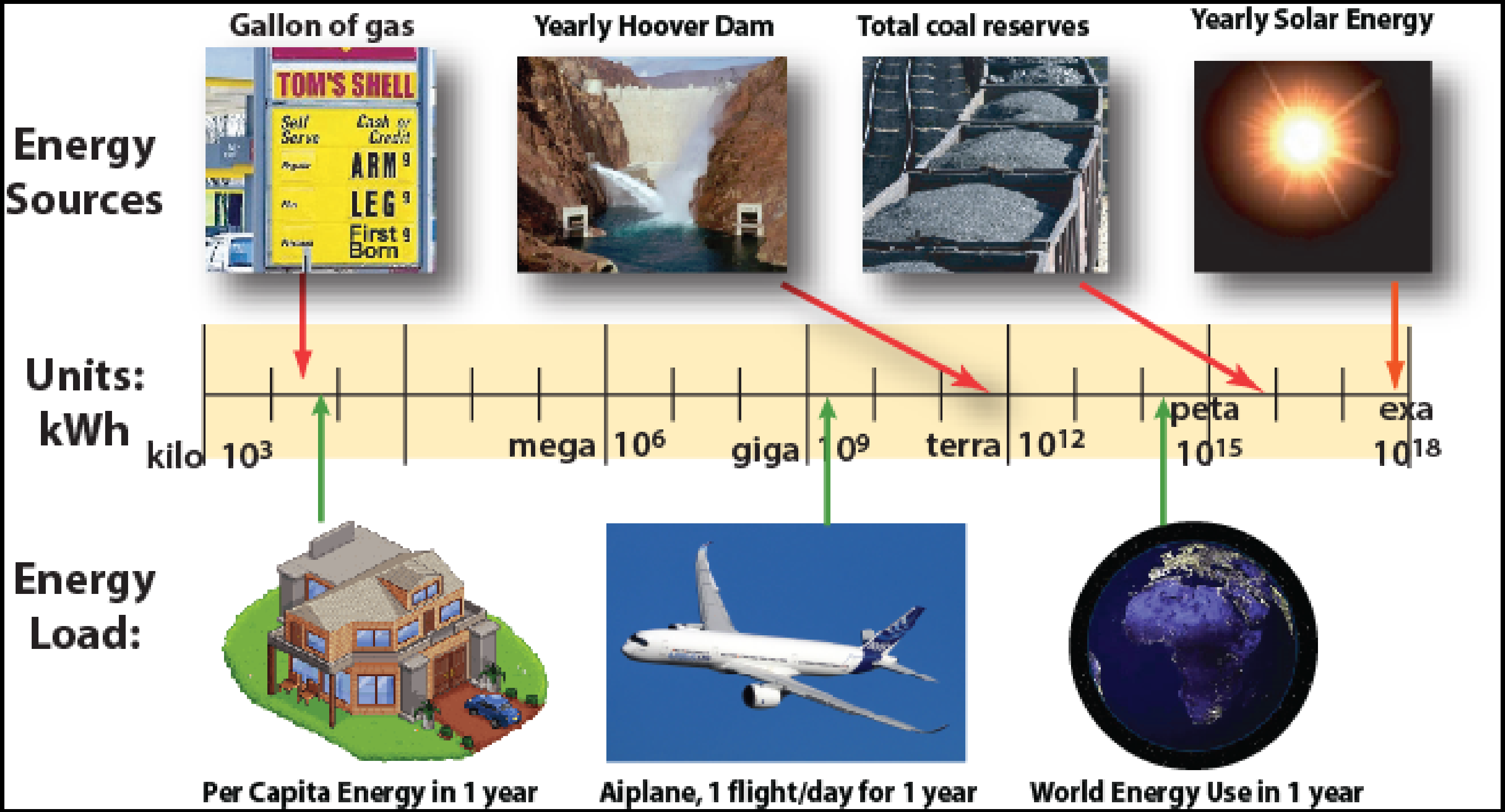
Dr. Honsberg is the Director of QESST,
an NSF-DOE Engineering Research Center

Moderator:
Trevor Thornton

Scale of Energy Systems

- The energy system is one of the largest infrastructure systems
- How will technology and societal views interact to shape it?



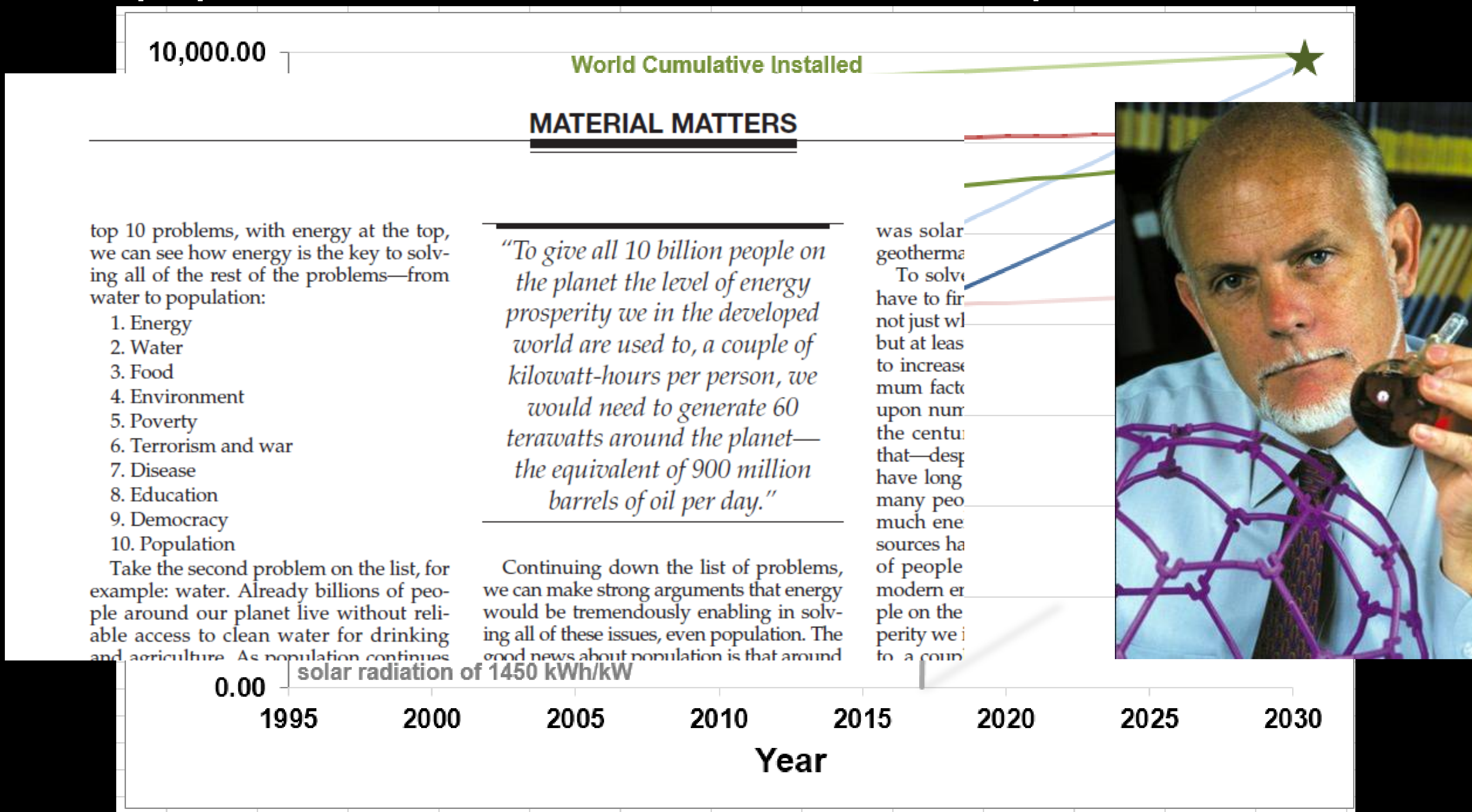
transportation energy transition

- Transportation – major infrastructure transition given impetus by environmental issues

1894, the Times of London estimated that by 1950 every street in the city would be buried nine feet deep in horse manure.

terawatt challenge

- In the two decades (famous paper 1995) since the TW challenge paper, renewables have reached multiple milestones



MATERIAL MATTERS

top 10 problems, with energy at the top, we can see how energy is the key to solving all of the rest of the problems—from water to population:

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism and war
7. Disease
8. Education
9. Democracy
10. Population

Take the second problem on the list, for example: water. Already billions of people around our planet live without reliable access to clean water for drinking and agriculture. As population continues

"To give all 10 billion people on the planet the level of energy prosperity we in the developed world are used to, a couple of kilowatt-hours per person, we would need to generate 60 terawatts around the planet—the equivalent of 900 million barrels of oil per day."

Continuing down the list of problems, we can make strong arguments that energy would be tremendously enabling in solving all of these issues, even population. The good news about population is that around

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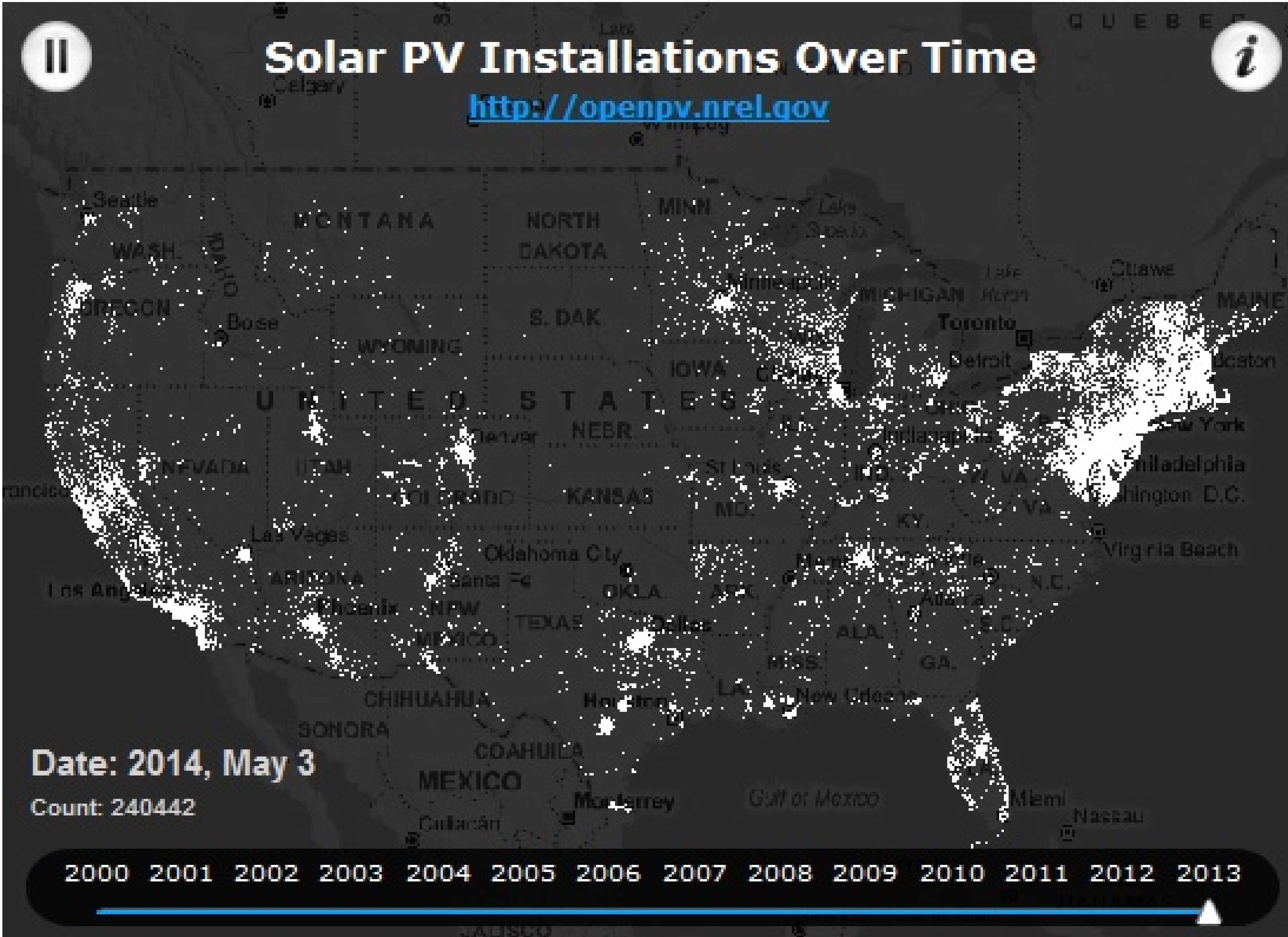
Solar PV Installations Over Time
http://openpv.nrel.gov
Date: 2014, May 3
Count: 240442
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Calgary
Seattle
WASH.
MONTANA
NORTH DAKOTA
MINN
OREGON
IDAHO
Boise
WYOMING
S. DAK
Minneapolis
MICHIGAN
Toronto
Detroit
Ottawa
MAINE
IOWA
UNITED STATES
NEBR.
Denver
NEVADA
UTAH
COLORADO
KANSAS
St Louis
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Indianapolis
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Virginia Beach
Las Vegas
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Houston
CHIHUAHUA
SONORA
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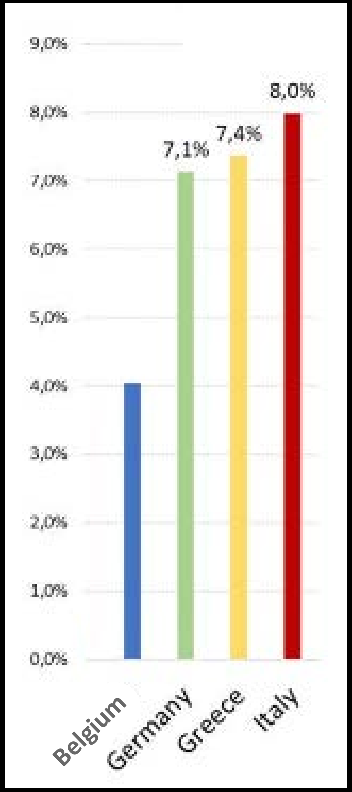
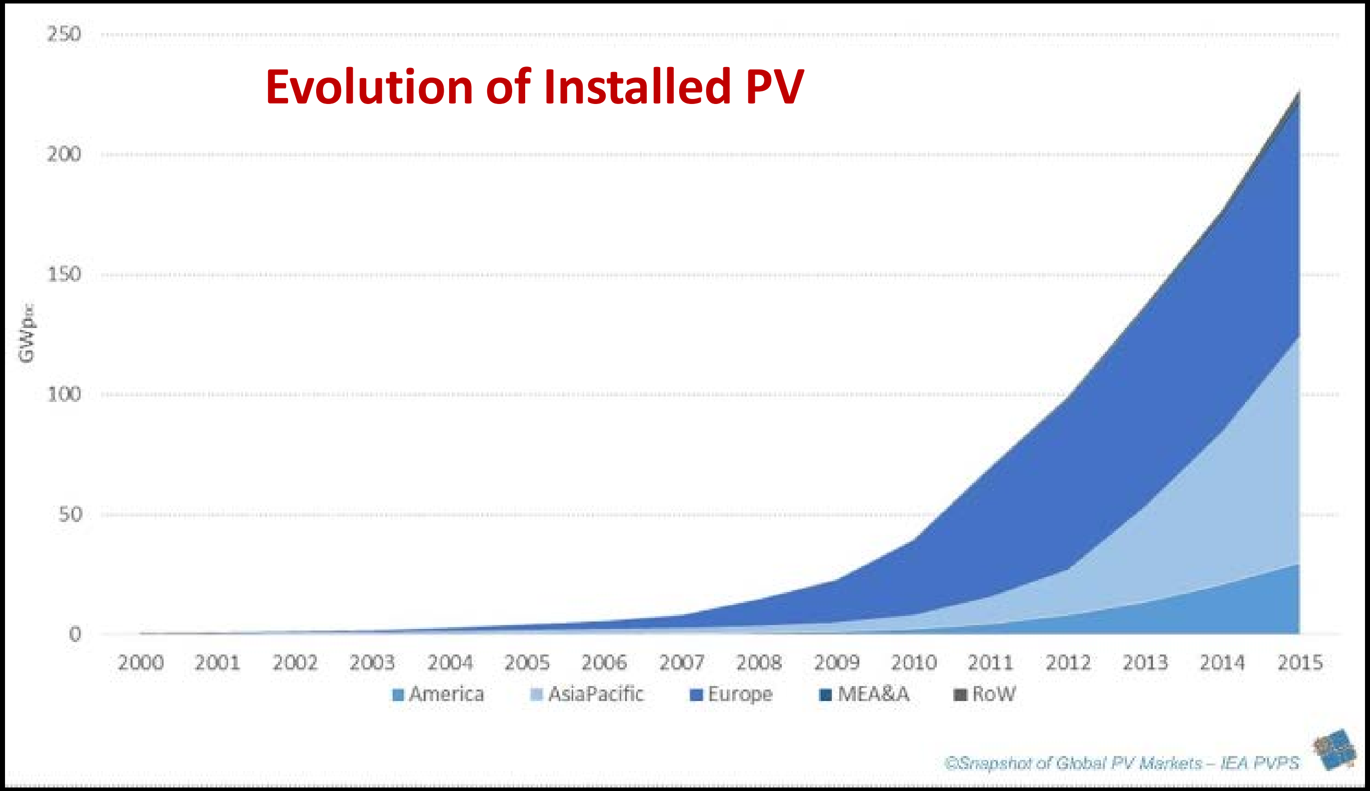
state of photovoltaic industry

Fraction of total electricity from PV

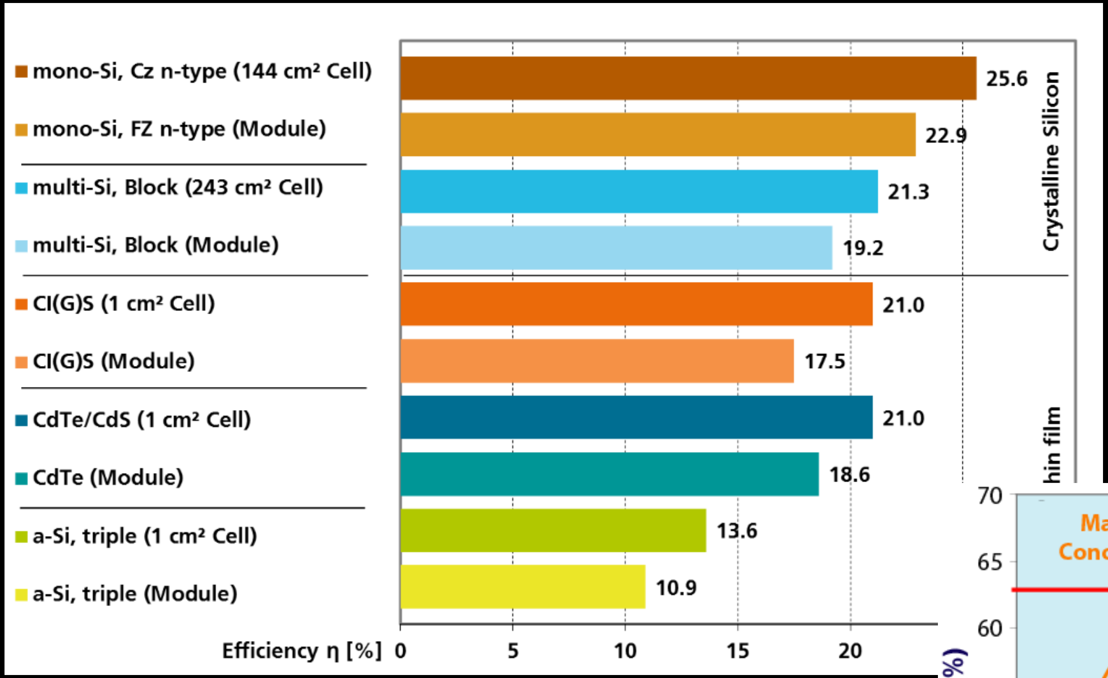


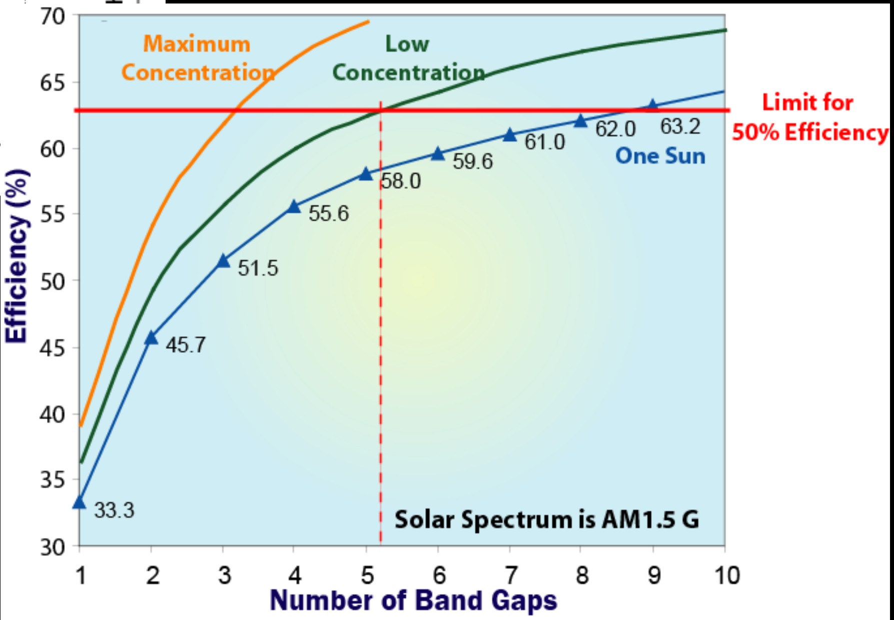


state of photovoltaic industry

- Two dominant technologies; silicon and thin film
- Silicon ~ 90% of industry; thin film is CdTe and CIGS

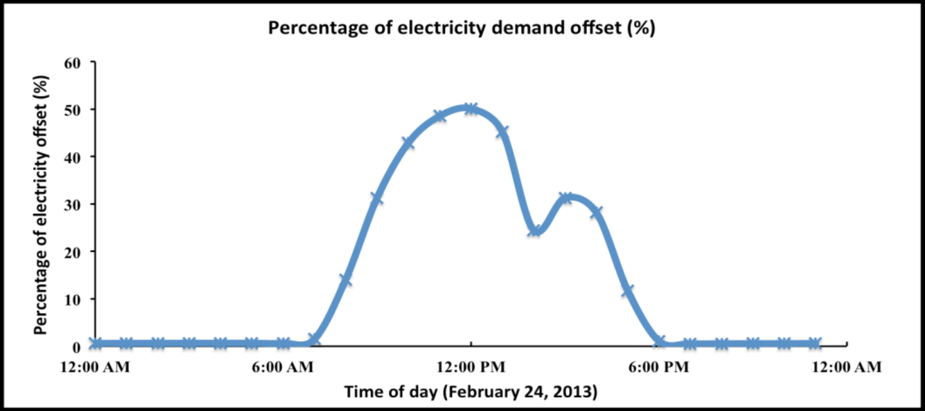
photovoltaic efficiency

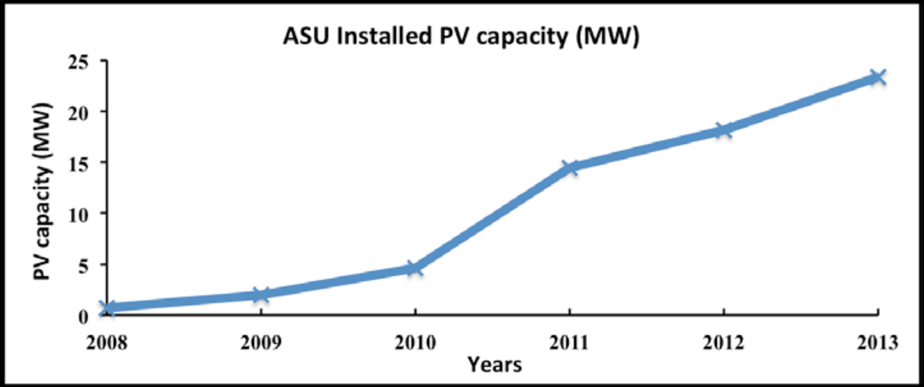




photovoltaic at asu

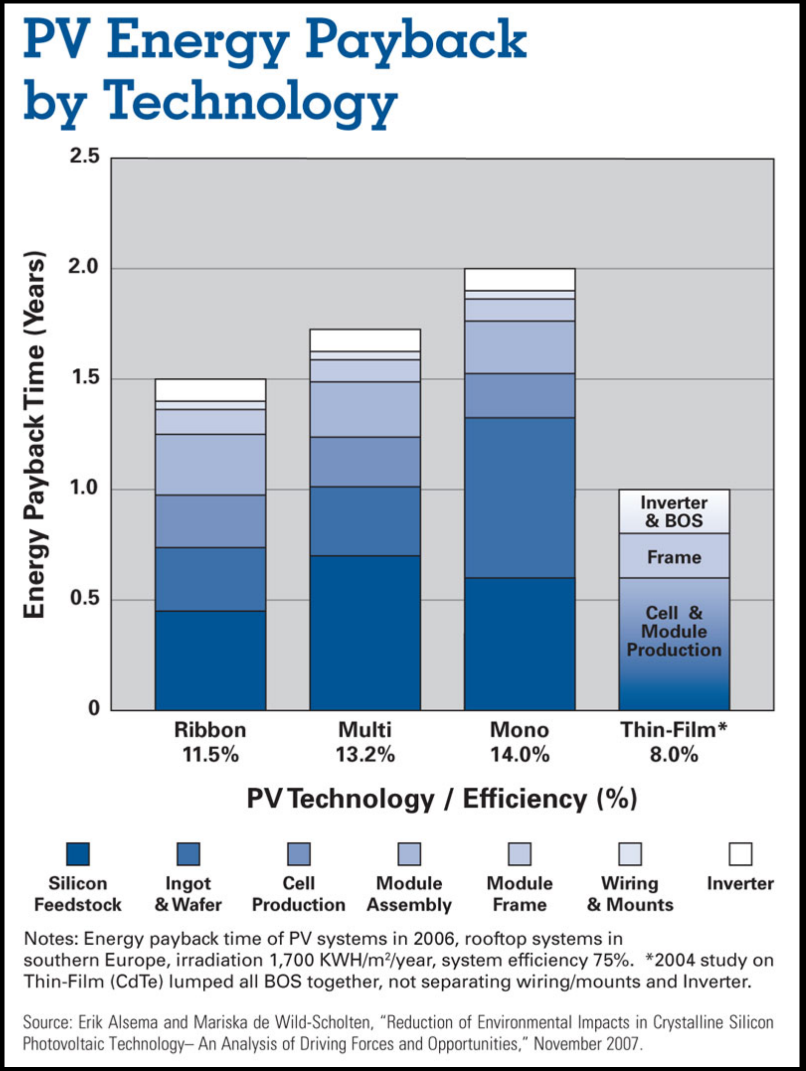
- ASU –50% of peak electricity supplied by PV; 20% of total electricity





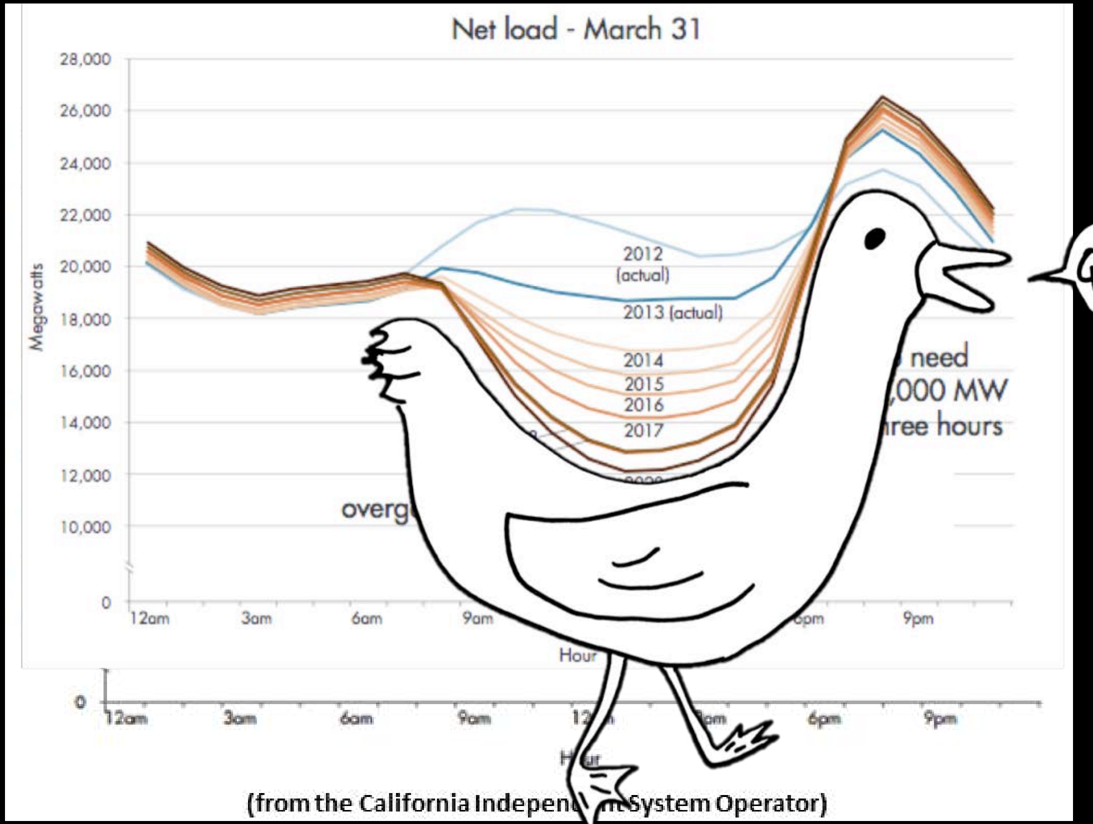
but what about….

- Energy payback time
  - Less than 1 year to 2 years depending amount of sun at a location
- Land use
  - Nuclear/Solar land use area ~ 1.8
- Energy density (same as Uranium)
- Materials availability
  - For silicon, limitation is silver in grids, which cause a limitation at 2 TW

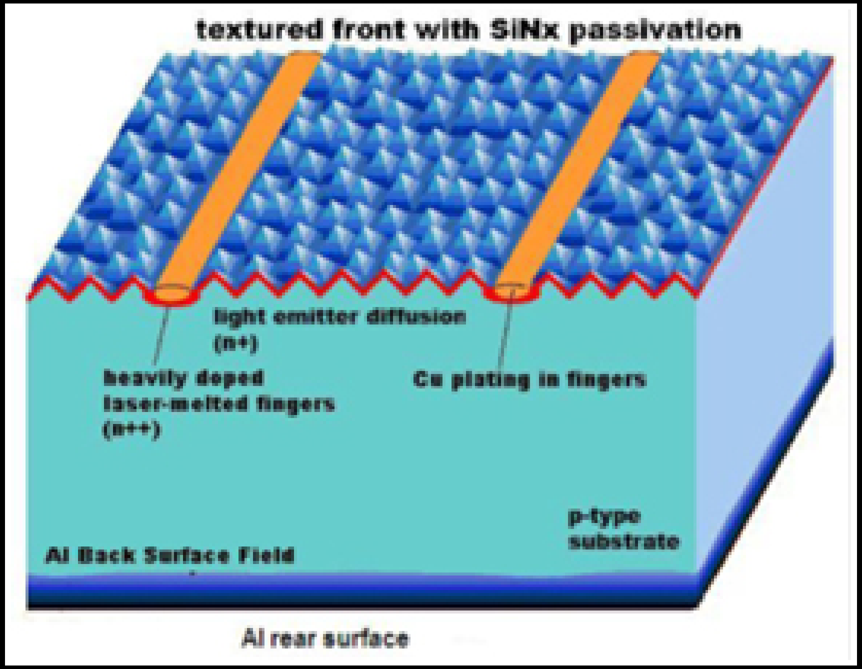


but what about.....

- Duck curves - grid integration and stability
  - Impacts the grid only under conditions where utilities are required to buy solar electricity.
  - Places economic pressure on photovoltaics and need for advanced technologies

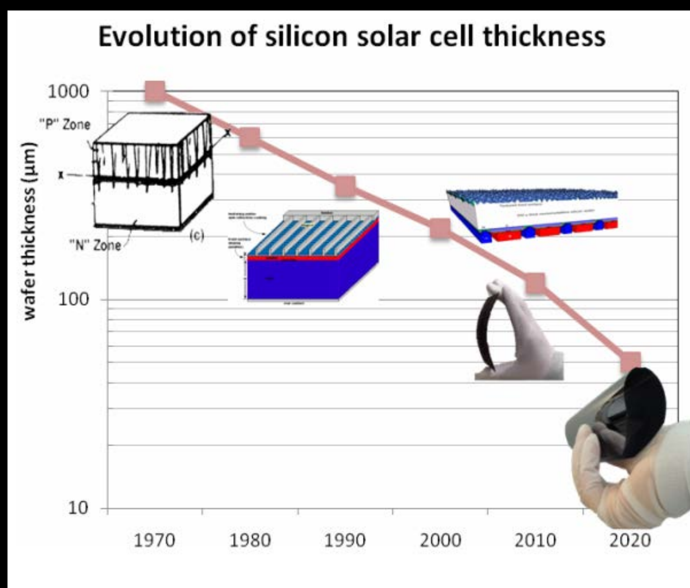


what to we need in photovoltaics



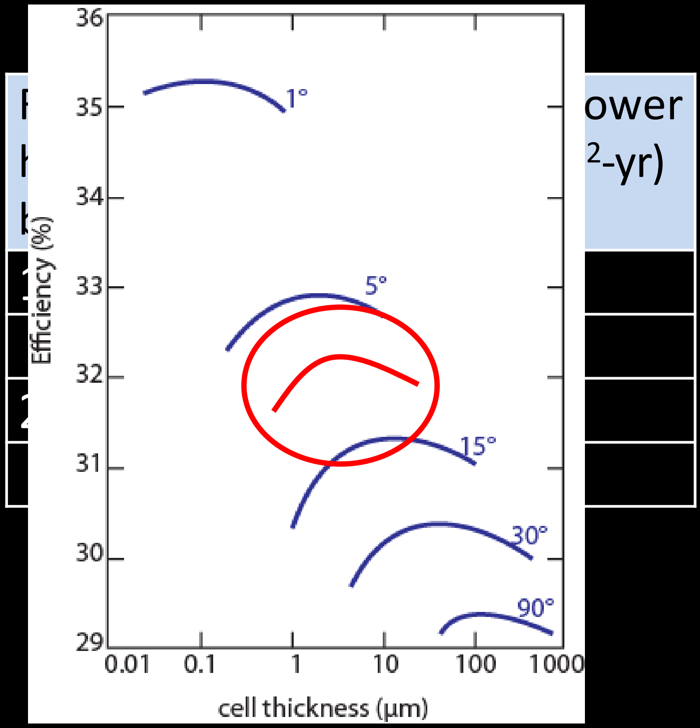
Moore's Law for photovoltaics

- Rapid semiconductor development tied to "Moore's Law" – cost and performance related to a technologically controlled parameter
- Solar cells increase efficiency as thickness is decreased



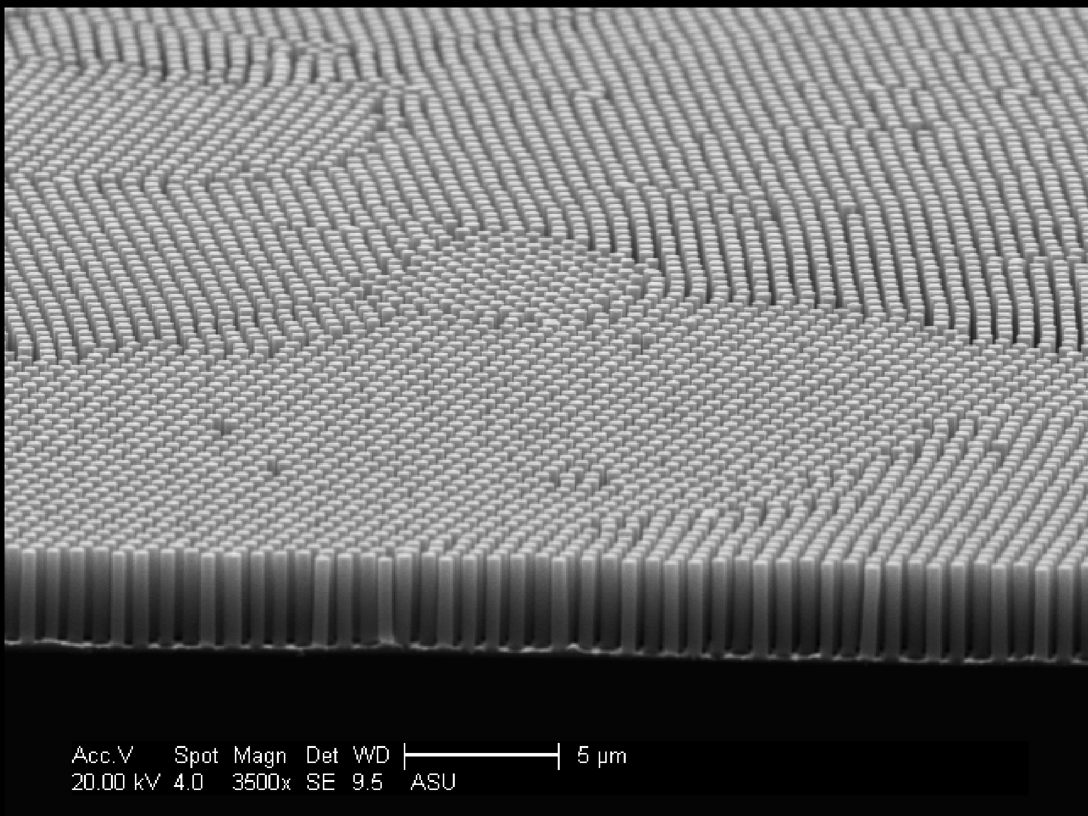
silicon single junction – path to 50%

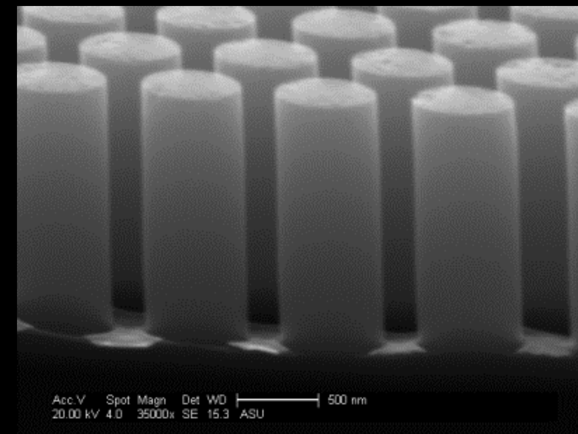
- Can exceed efficiency limit using optical approaches
- Very few photovoltaic systems "see" sunlight for 180 acceptance angle due to angle dependence of reflection, buildings, etc.
- Rejecting the horizon band allows smaller acceptance angle without power loss over the year



photonic control for solar cells

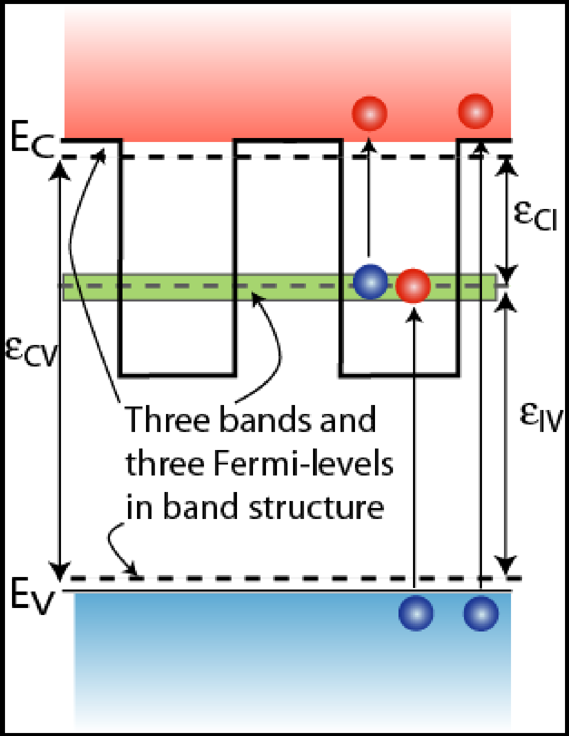
- New approaches for light trapping for thin solar cells

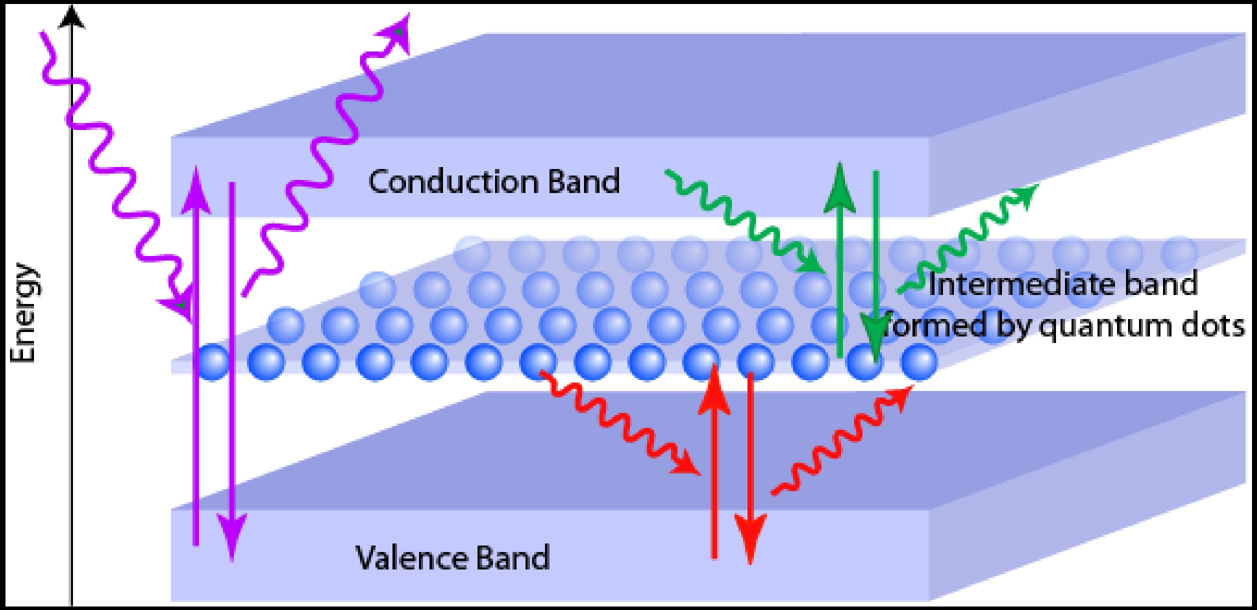




nanostructures in photovoltaics

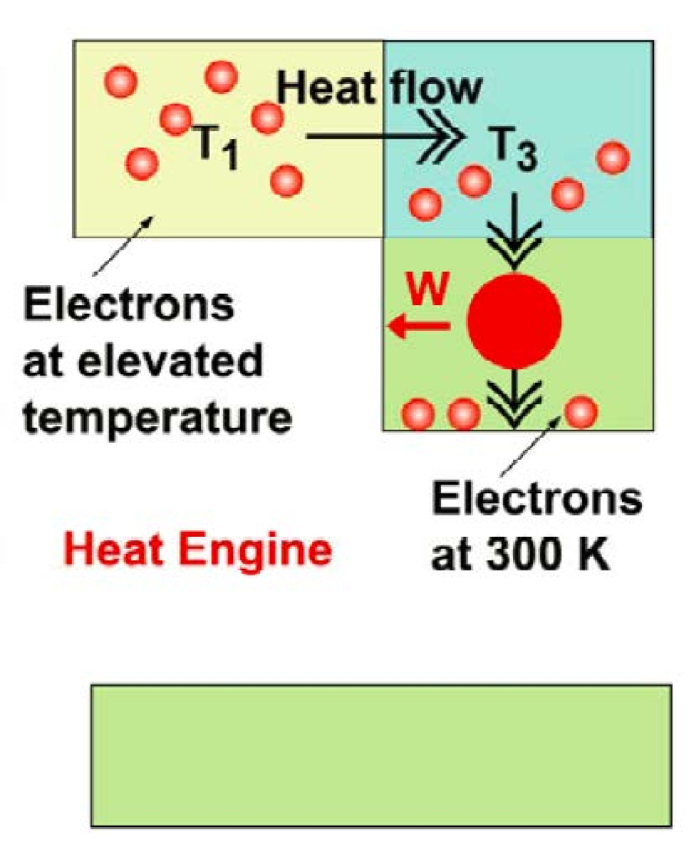
- Control over electronic structure
- Quantum dots enable multi-color operation of photovoltaics
- Dramatically changes material properties

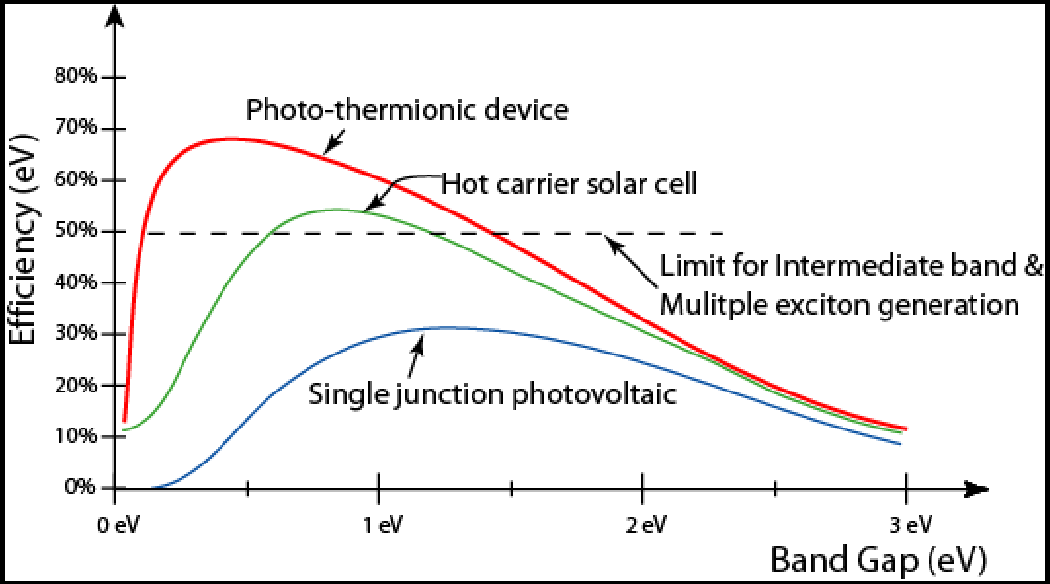




advanced approaches

- Nanostructures enable control over electrons, photons and heat transfer





Thermodynamics tells us we are nowhere near the efficiency potential, for ANY of the technologies

thermodynamics & technology

“we wanted flying cars and we got 140 characters”

what can we do with the energy?

– Several TW installed capacity can extract and convert CO_2 in atmosphere.

…0% of California's water needs by

…space (much bigger than TW)

…on –

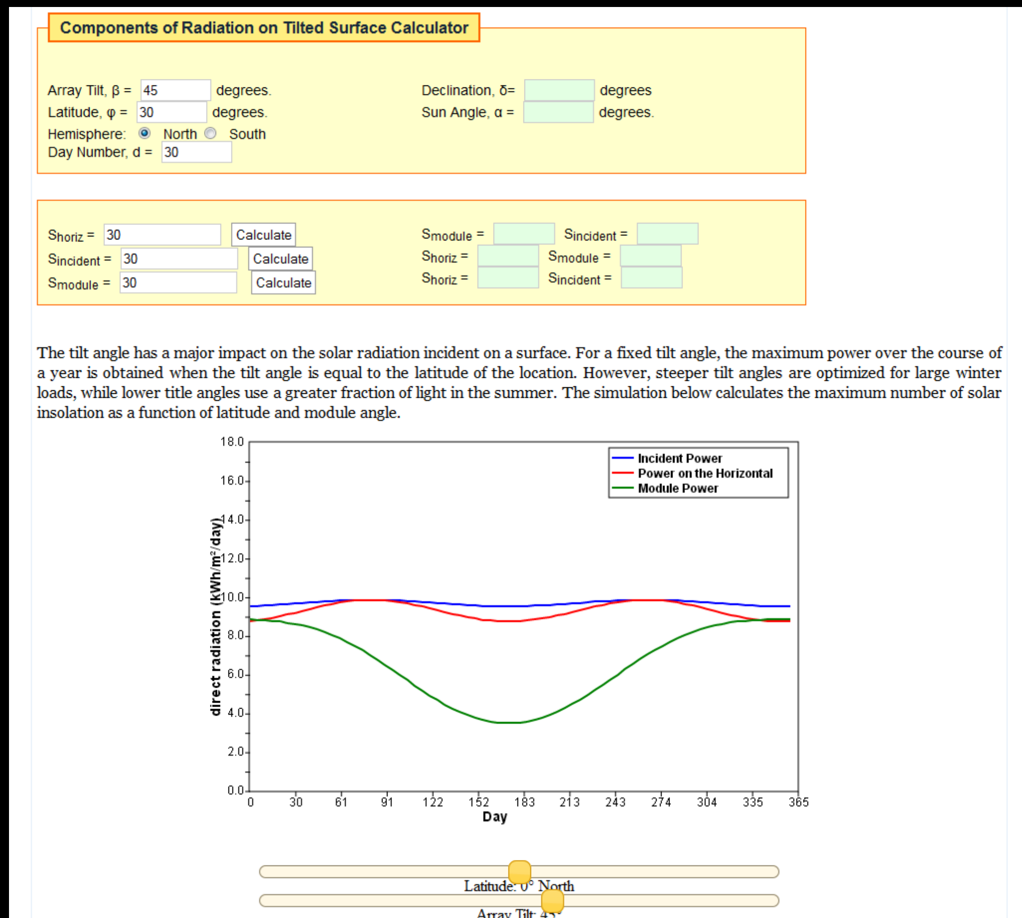
…ctly interact

future of photovoltaics

- Thermodynamics tells us nearly anything is possible.
- The best options depend on imagination and involving society in shaping the future
- The moonshot showed the world that science can change what society believes is possible

Pveducation.org

- More information on solar on www.pveducation.org



Thank you.

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