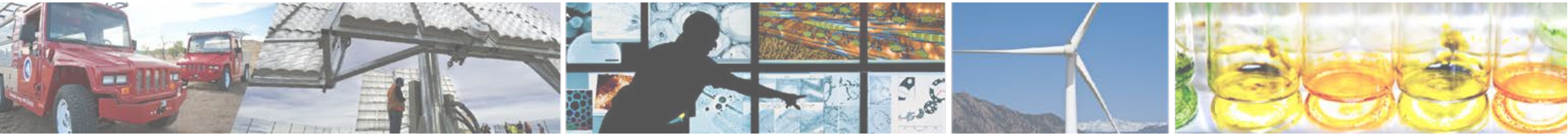


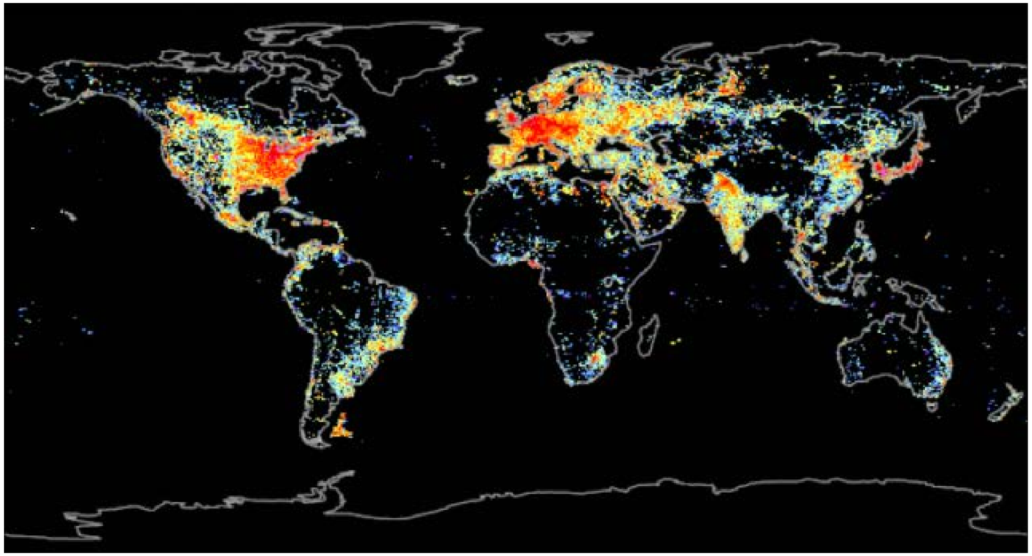
A PV Powered Earth by 2040

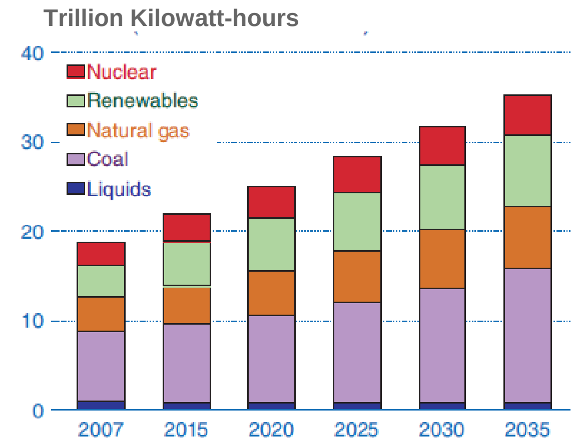
2014 SunShot Summit

Greg Wilson
Director, National Center for Photovoltaics
National Renewable Energy Laboratory
Golden, Colorado - USA

21 May, 2014

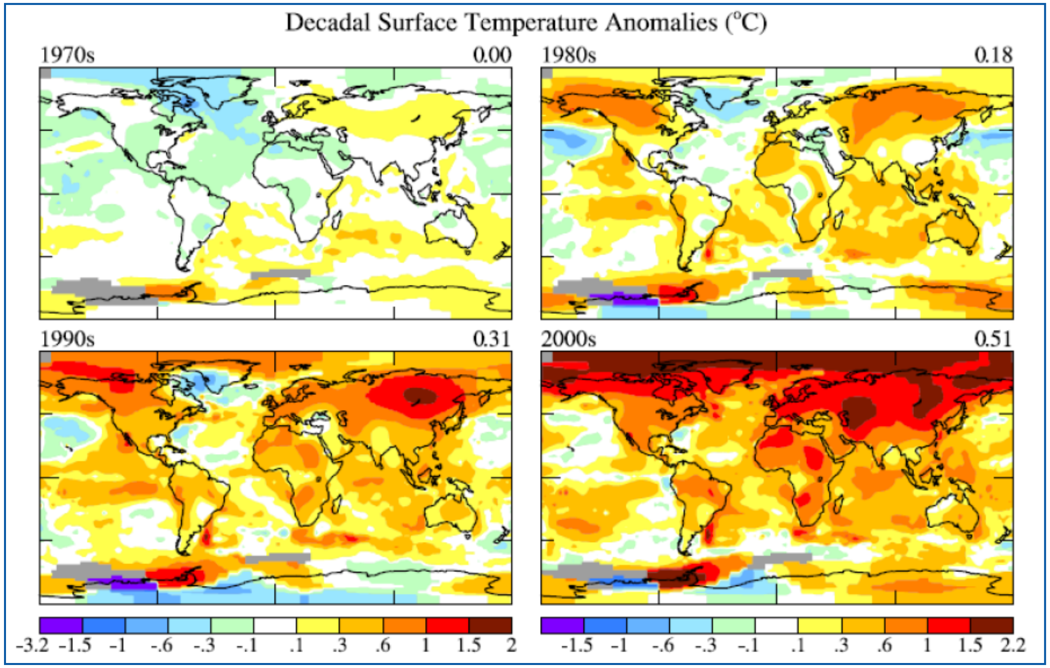
An Energy & Climate Change Challenged World

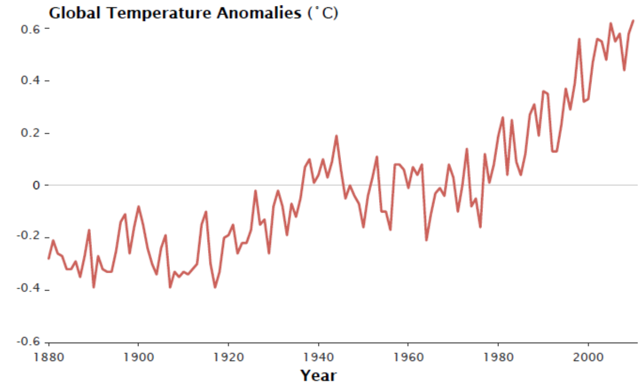




Source: 2010 DOE-EIA International Energy Outlook

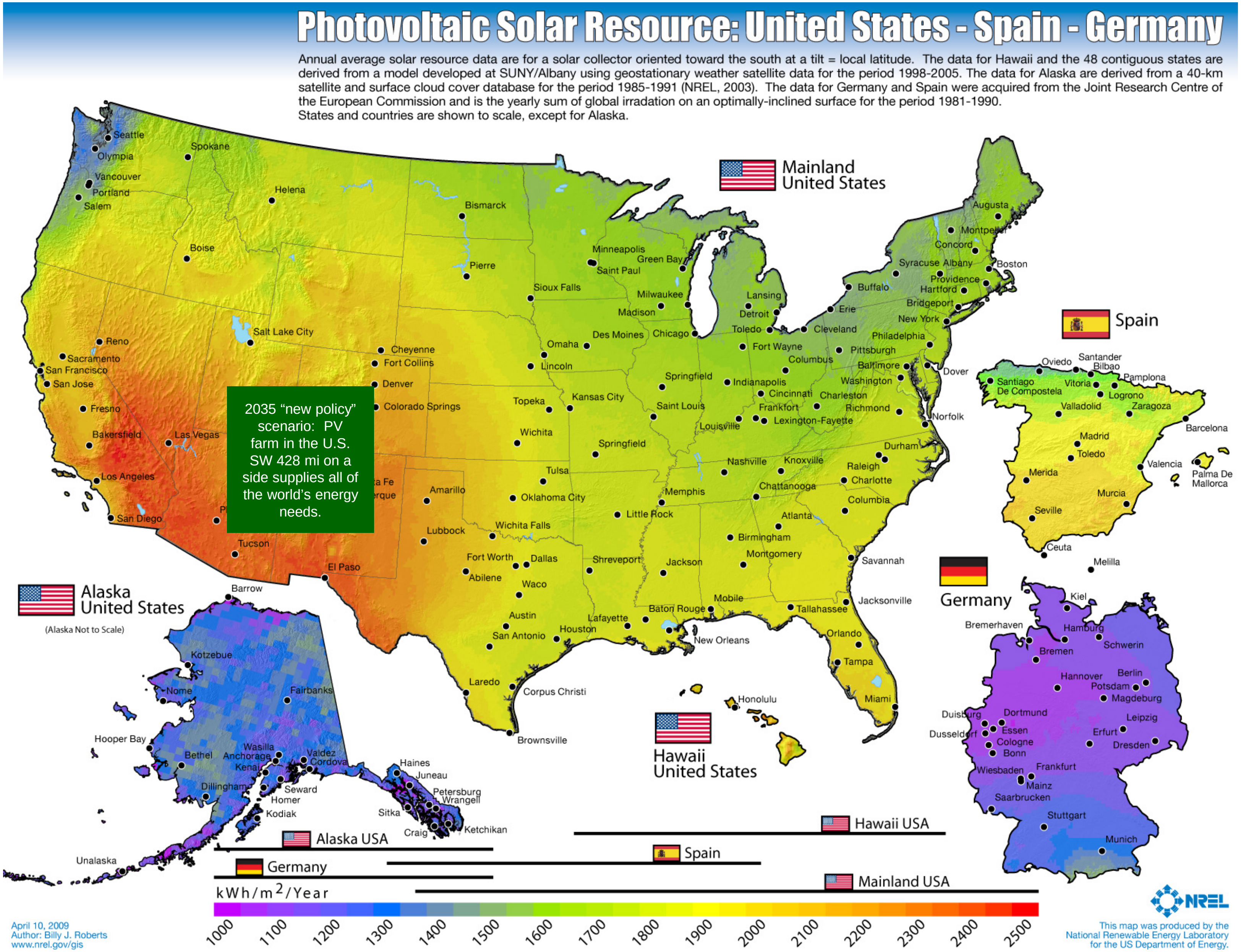
- **~21 trillion kWhrs of electricity, ~2/3 from fossil fuels.**
- **Earth at 400ppm CO_2.**





Source: NASA-GISS

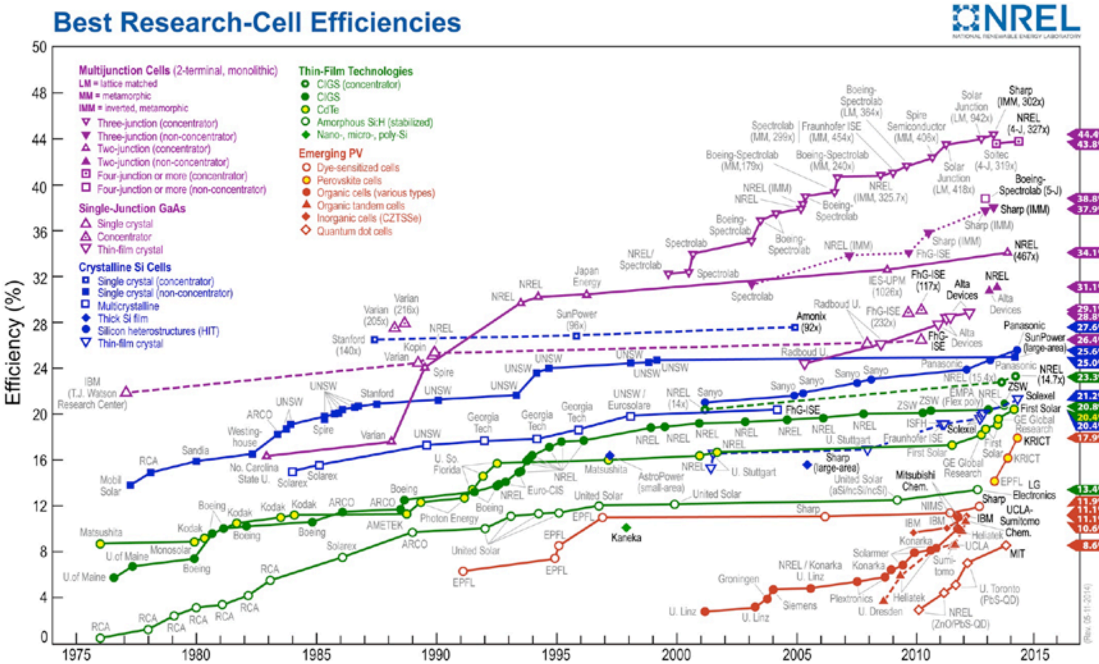
PV Energy for Planet Earth



PV in 2040

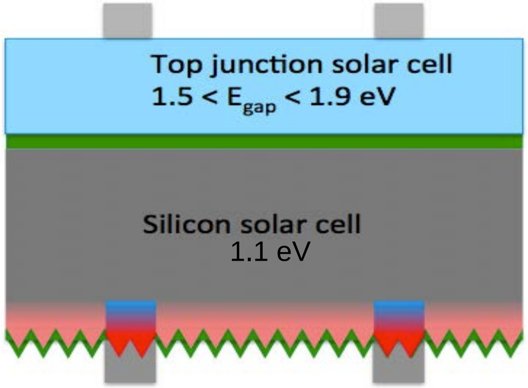
- The combination of a climate change challenged world and the emergence of PV as one of the lowest cost generation sources will create large demand pull that will drive PV technology innovation.

- The market for PV systems will have expanded to cover a wide range of system efficiencies, service lives and aesthetic features (for BIPV systems).



- This market will be highly segmented and highly competitive, much like today’s automobile market.

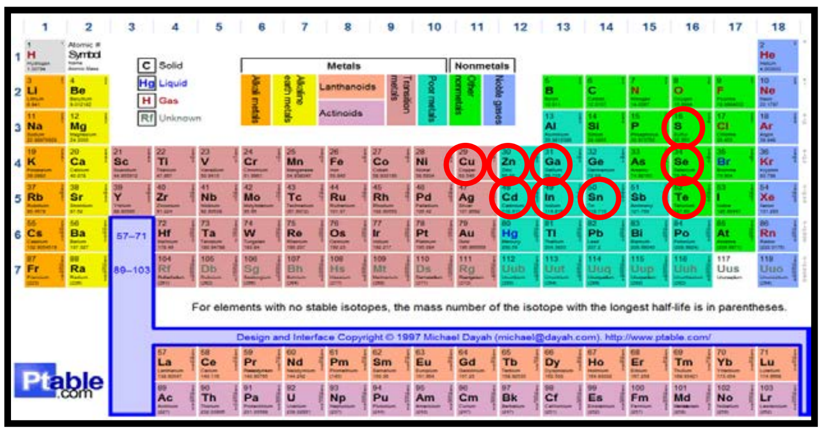
PV in 2040: High η from Columns III-IV-V

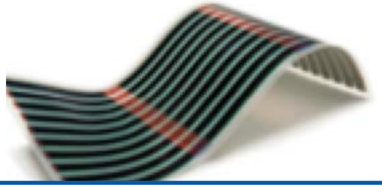


- The highest efficiency ground mounted cSi systems installed in the next few years will be nearing the end of their service lives.
- Lower efficiency systems will have already been replaced by a new generation of low-cost, 25 – 35% efficient systems based on multi-junction PV technologies, and much of this will still use bottom cells made using single crystal Si.
- Another portion of this market will not use cSi at all and will utilize various III-V PV absorbers produced using very low cost epitaxy and next generation layer transfer and bonding technologies.

PV in 2040: Next Gen Thin Films

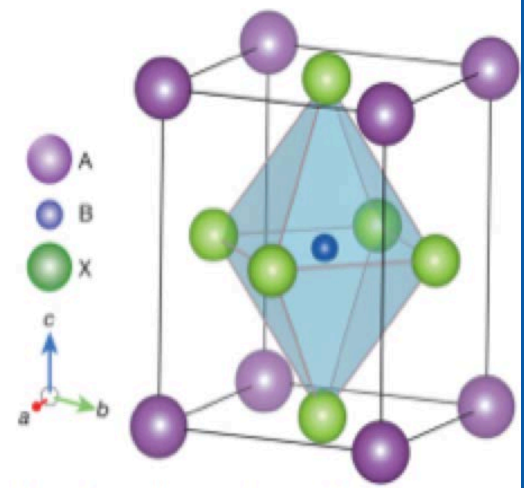
- Building integration of PV will be dominated by roofing systems that include PV cells that are matched both in cost and service life to the roofing system.
- Lower cost flexible roofing systems will use lower cost, shorter service life PV absorbers made from organic, organic-inorganic hybrid (perovskite?) and inorganic binaries, ternaries and quaternaries.





Organic-Inorganic Lead Halides Perovskite

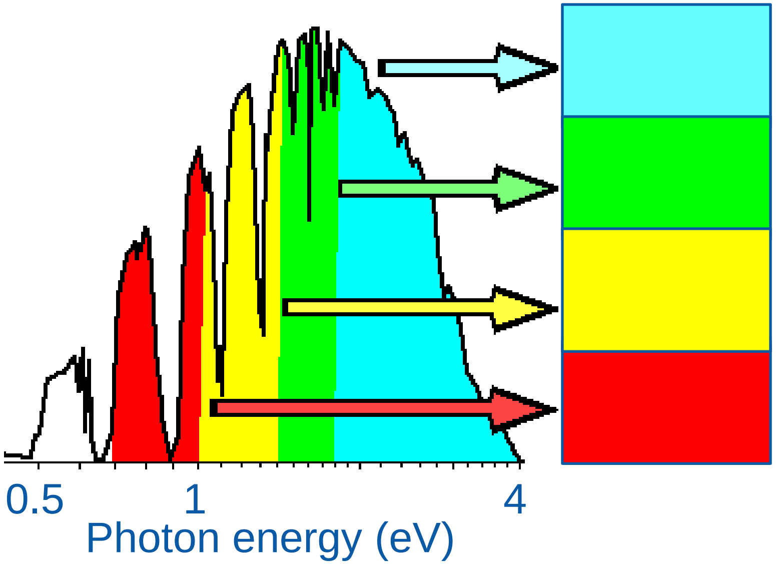
X = **Cl^-**, **Br^-**, **I^-**
B = **Pb**, Sn, Ge
A = ORGANIC **($CH_3NH_3^+$)**



Liu et. al., Nature 2013

PV in 2040: Building Integrated PV

- Higher cost, longer lifetime roofing systems will integrate higher efficiency PV technologies that may utilize either single or multi-junction cells.



- Silicon will still be a player (thin absorber, epitaxially grown on low-cost seeds) but it will be accompanied by III-Vs at the high end of the efficiency scale.
- The cost of integrating PV will have dropped to the point that PV is also integrated into building exterior walls and windows but again, efficiency, service life and aesthetics will determine which technologies win.

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Thank You