



# The great adventure of Photovoltaics



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Photo from <http://www.cbspowersolutions.com>



# The adventure began long ago in a sunny land



photo from Africa Clean Energy Corridor, IRENA 2015



# Ancient and modern civilization

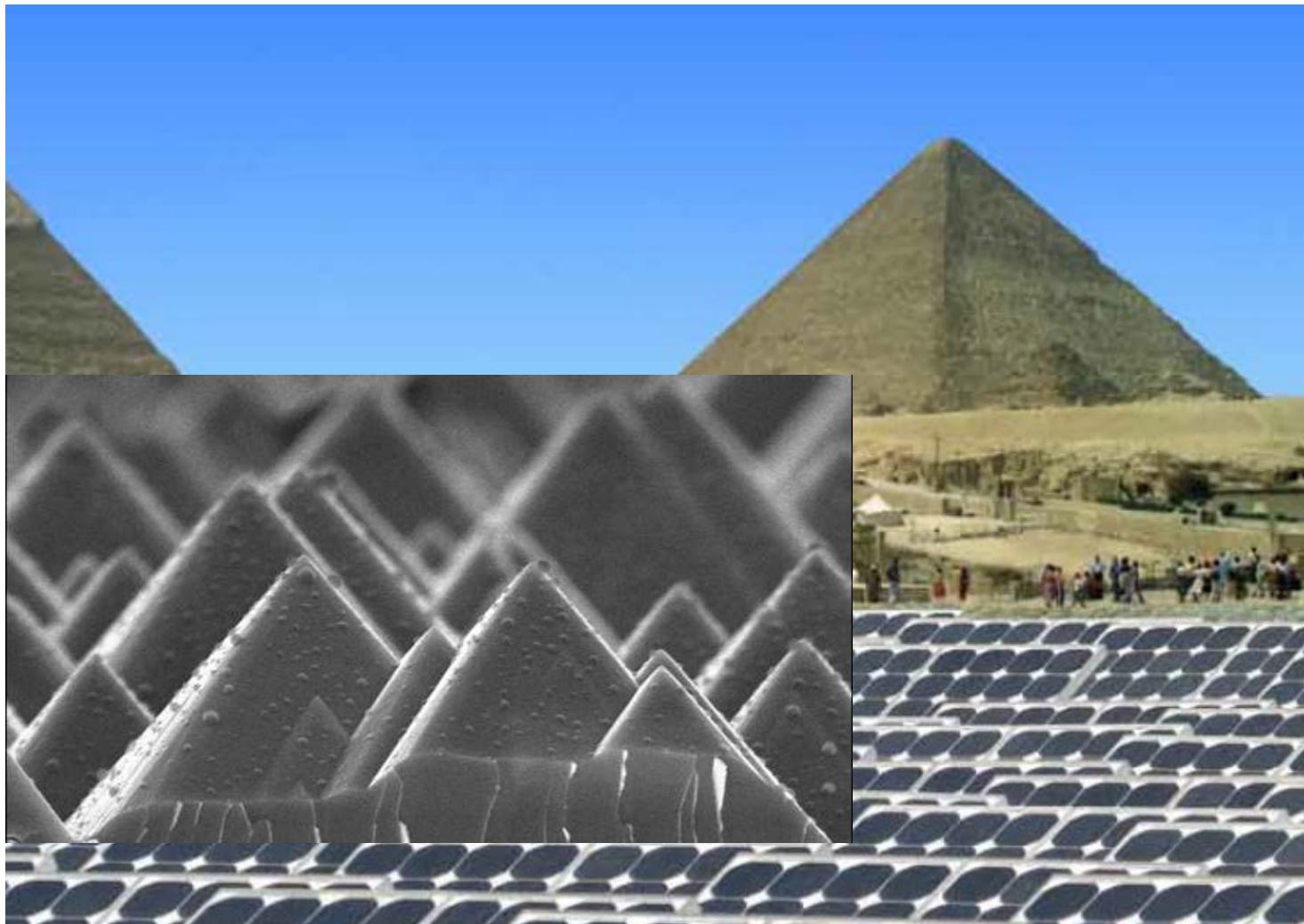
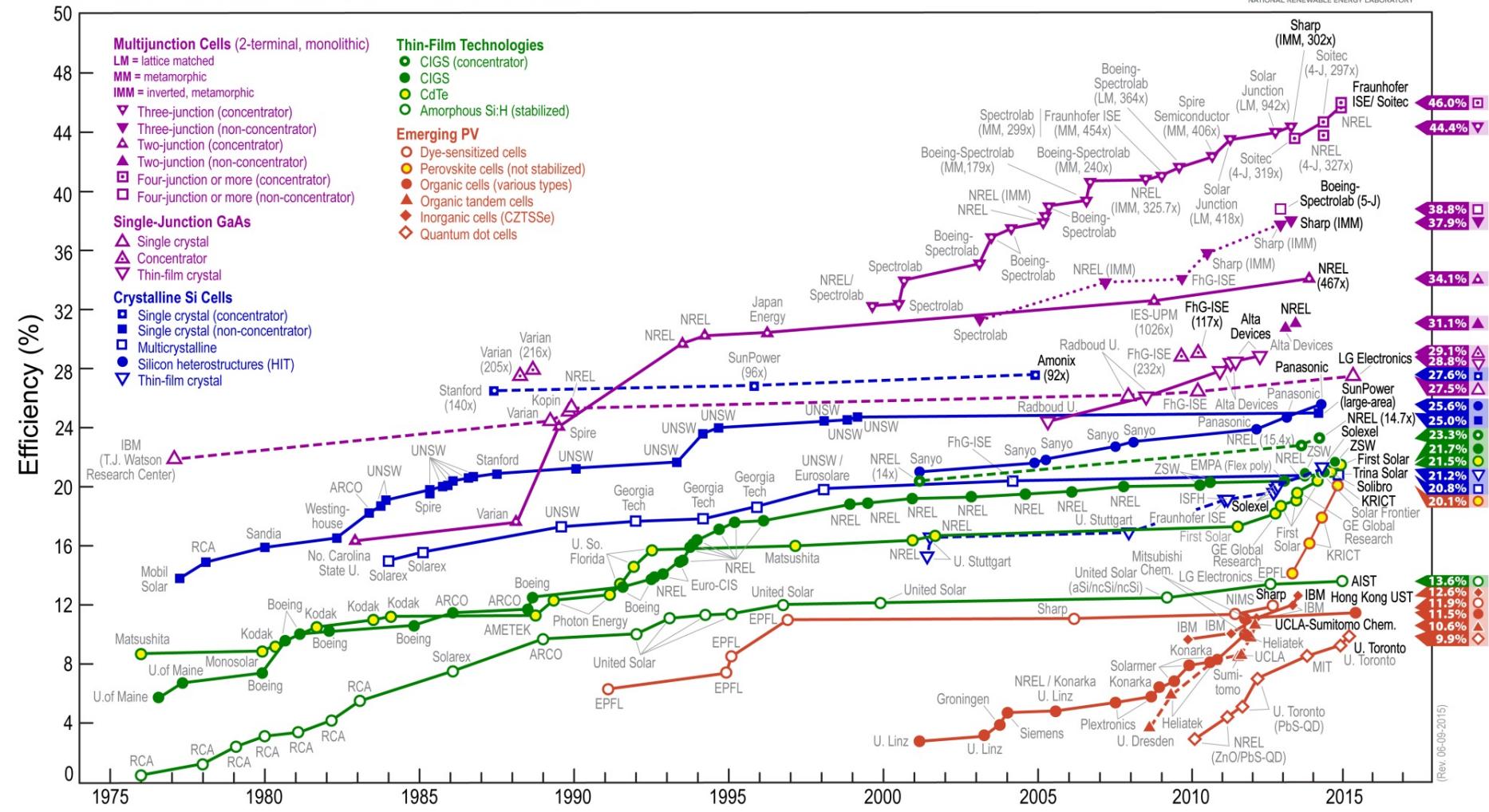


photo from Africa Clean Energy Corridor, IRENA 2015



# The scientific adventure: a staircase to the sun

# Best Research-Cell Efficiencies





# Alexandre Edmond would be pleased

incroyable!  
magnifique!  
formidable!



Edmond Becquerel



# Scientific curiosity



Edmond Becquerel

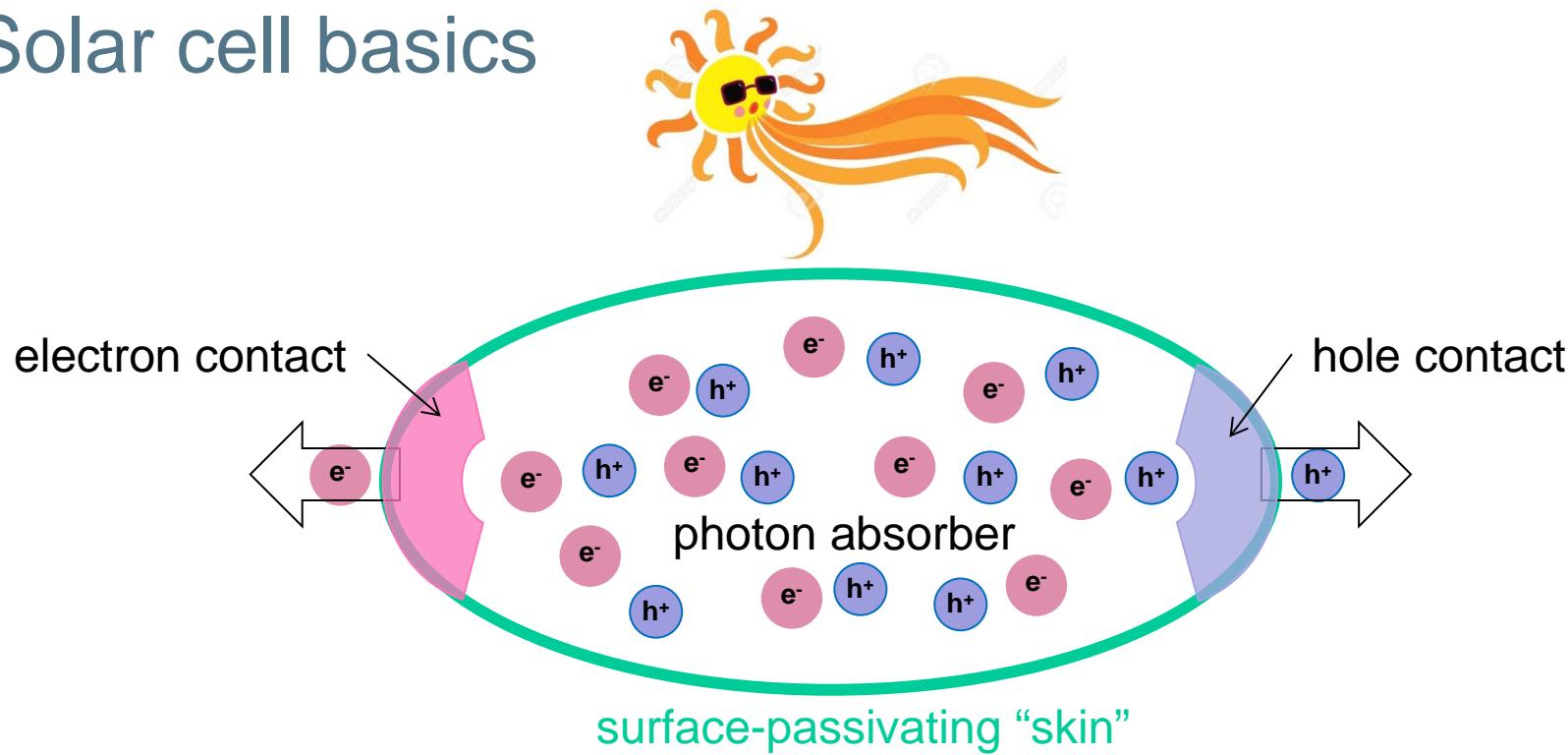


From Principles to New Concepts





# Solar cell basics

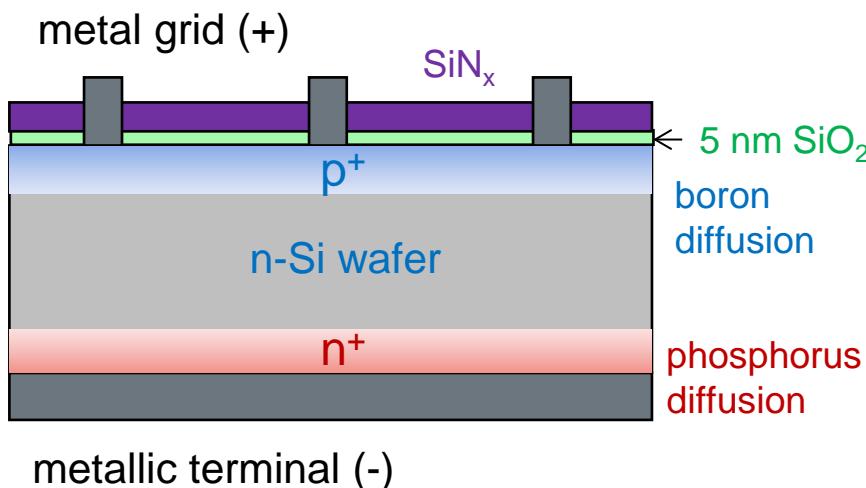


## Rules

1. Promote photogeneration
2. Suppress recombination, **everywhere!**
3. Facilitate the flow of electrons towards one terminal
4. Create a conductive path for holes towards the second terminal



# “Ancient” silicon solar cells (ca. 1978)



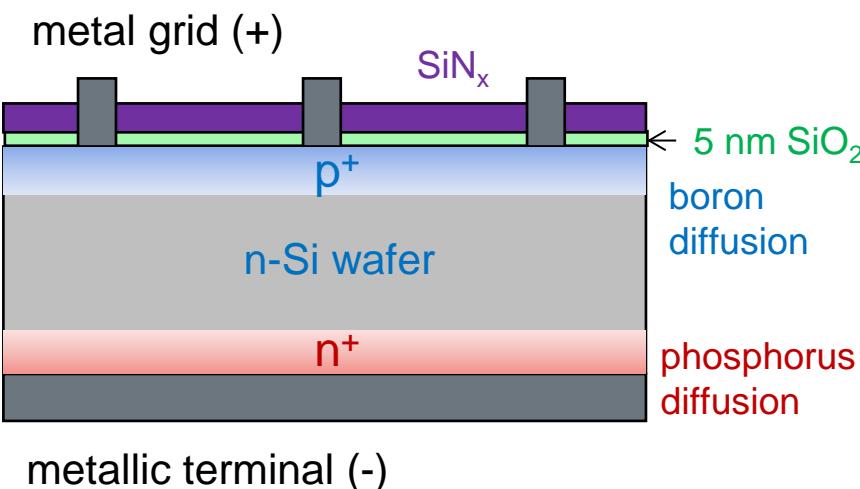
## **p<sup>+</sup>nn<sup>+</sup> cell (Sandia Labs)**

16.8%,  $V_{oc}=622 \text{ mV}$

(J. Fossum and E. Burgess, APL 1978)



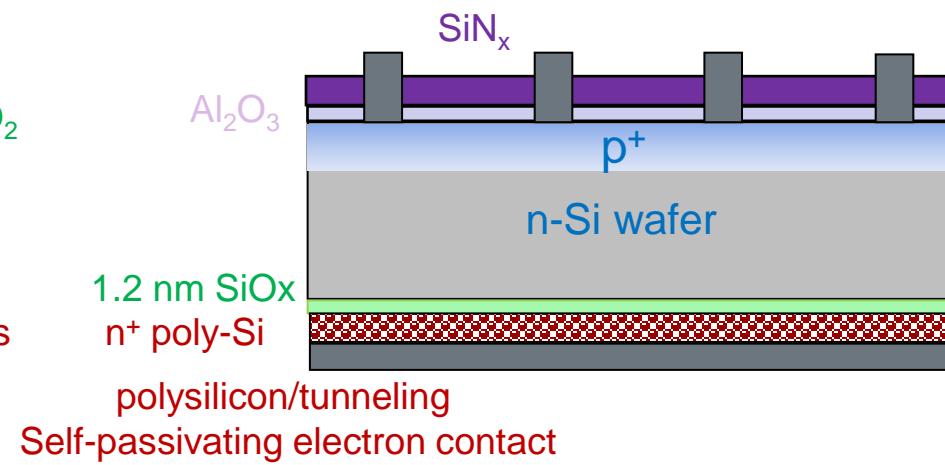
.....and what is hot now



### p<sup>+</sup>nn<sup>+</sup> cell (Sandia Labs)

16.8%,  $V_{oc}=622$  mV

(J. Fossum and E. Burgess, APL 1978)



### p<sup>+</sup>n/SiO<sub>x</sub>/n<sup>+</sup> polySi cell (ANU)

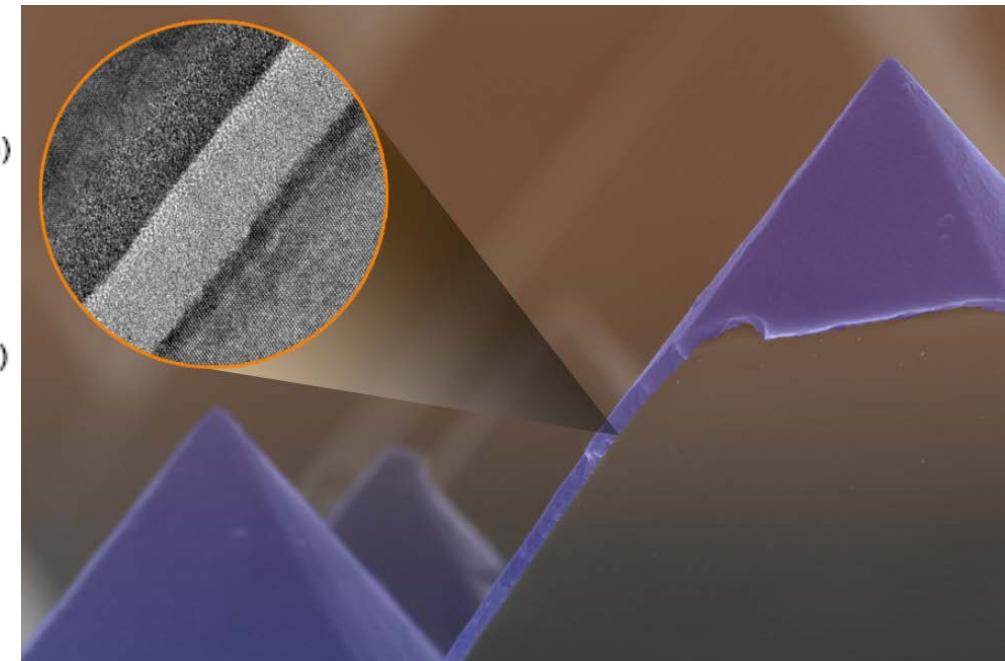
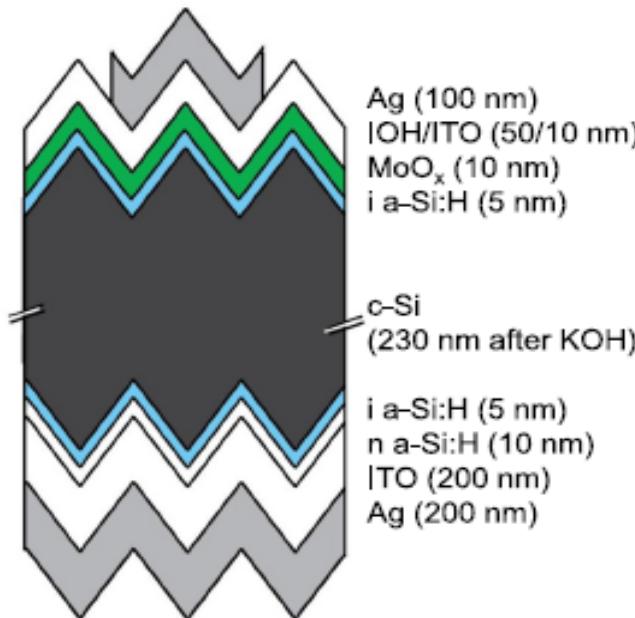
20.8%,  $V_{oc}=675$  mV

(Di Yan et al., Solar Energy Materials, 2015)



# What is cool: self-passivating contacts

hole contact  
 $\text{MoO}_x$   
 $\text{a-Si:H(i)}$   
  
 $\text{a-Si:H(i)}$   
 $\text{a-Si:H(n<sup>+</sup>)}$   
electron contact



from apl.aip.org

## **MoO<sub>x</sub>– Si heterojunction (EPFL)**

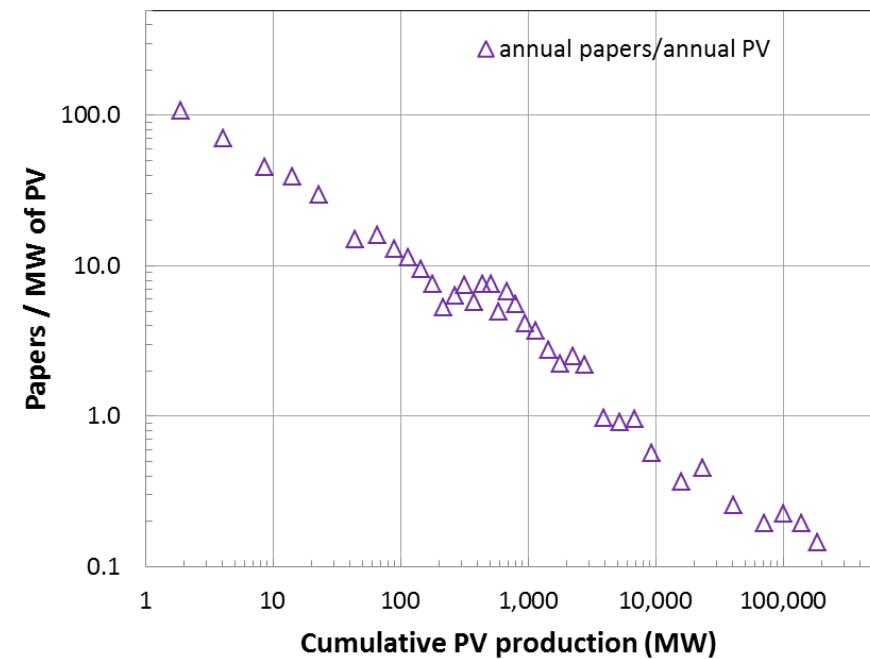
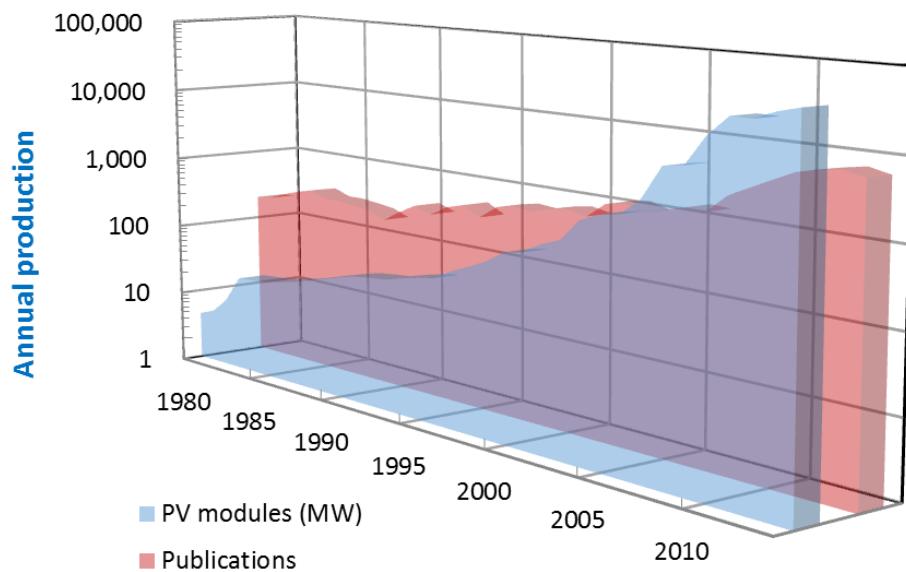
22.5%,  $V_{oc}=725$  mV

(J. Geissbühler et al., APL 2015)

“new” materials deposited at very low temperature



# “Learning curve” of PV science



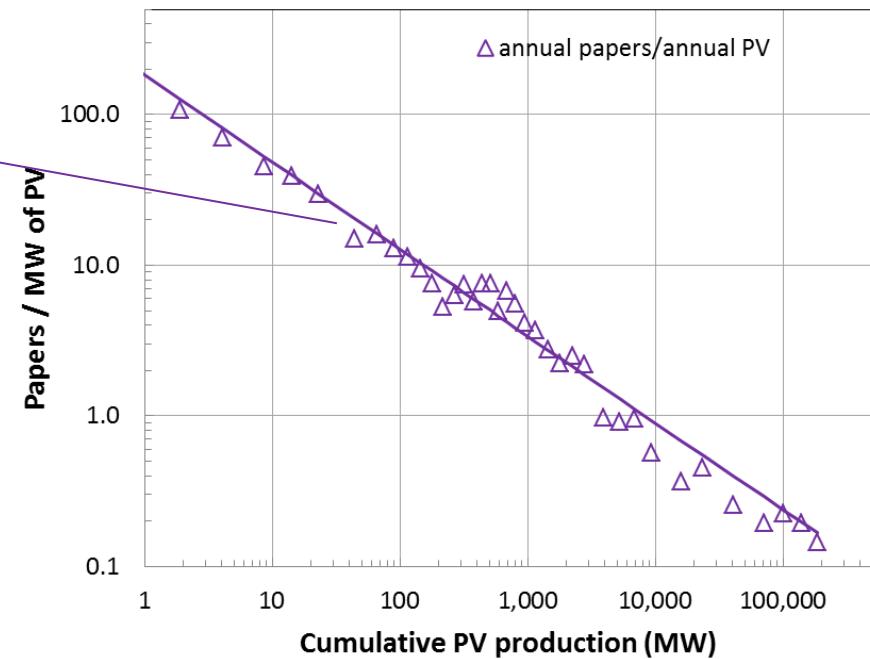
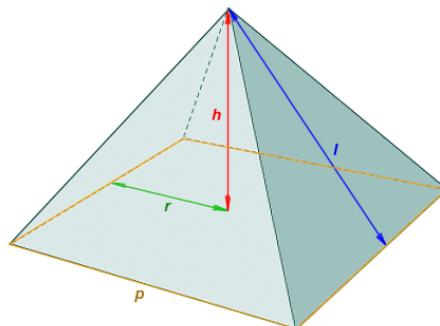
Preliminary analysis  
by Black and Cuevas



# The inexorable law of the pyramid

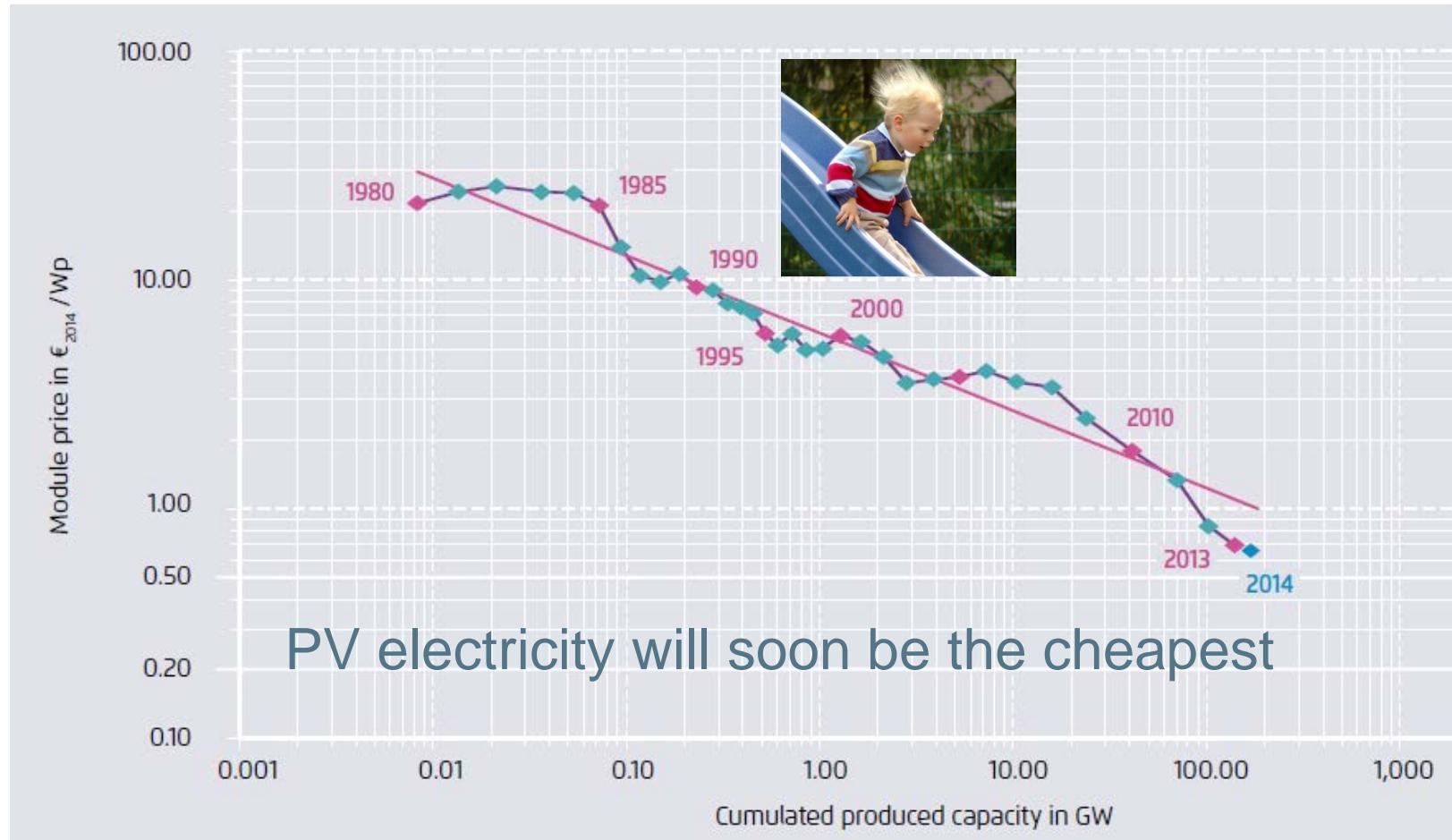
$$\frac{papers}{MW} = (MW_{cum})^{-\frac{1}{1.7}}$$

$$\frac{\text{flat surface}}{\text{pyramid surface}} = \frac{1}{1.7}$$



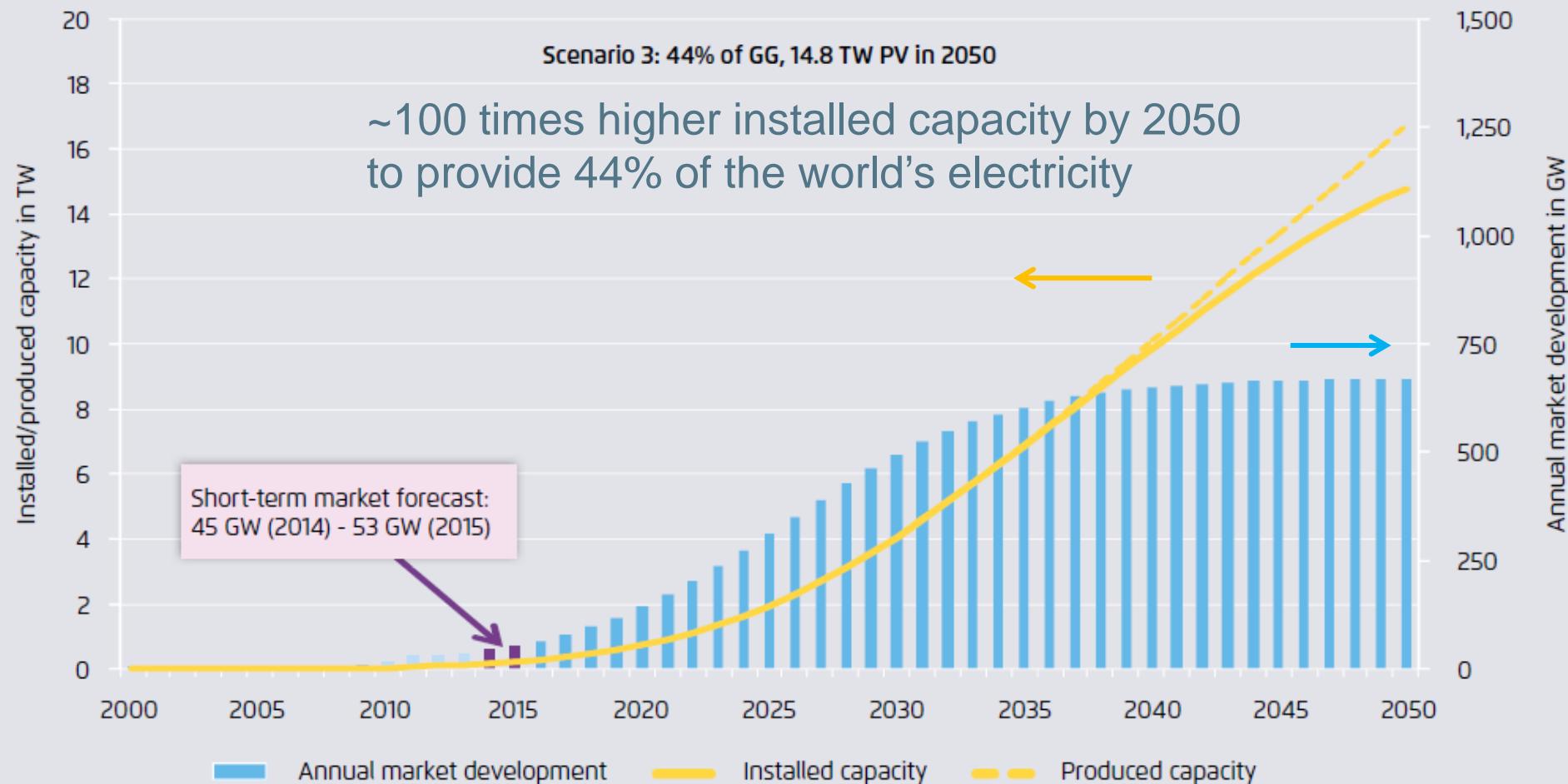


# PV technology is unstoppable!



Fraunhofer ISE (2015): *Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems*. Study on behalf of Agora Energiewende

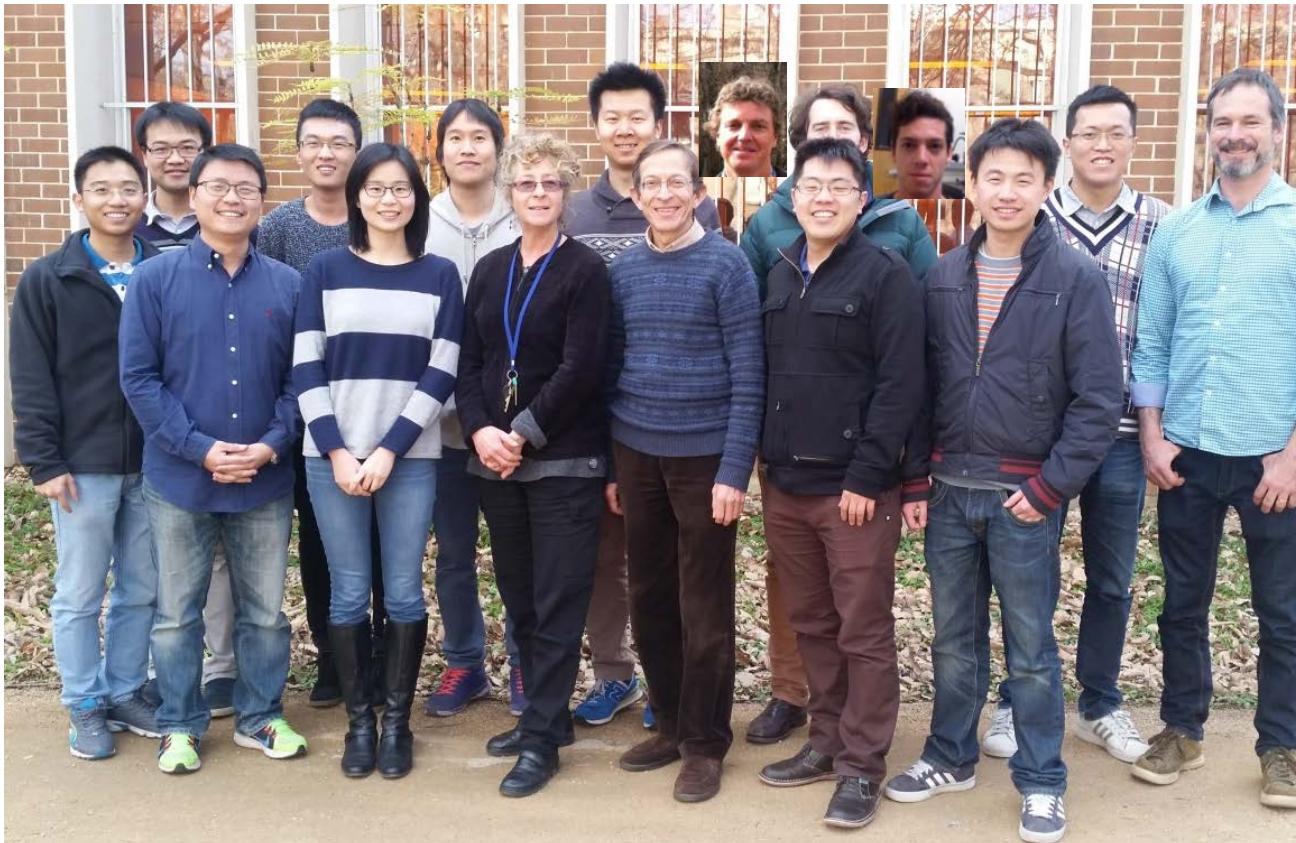
# Yes, PV can



Fraunhofer ISE (2015): *Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems*. Study on behalf of Agora Energiewende



# The adventure continues



The Cuevas-Macdonald group

Thank you all for sharing the dream of solar energy!