ORGANIC PHOTOVOLTAICS: FUTURE PROSPECTS AND CHALLENGES

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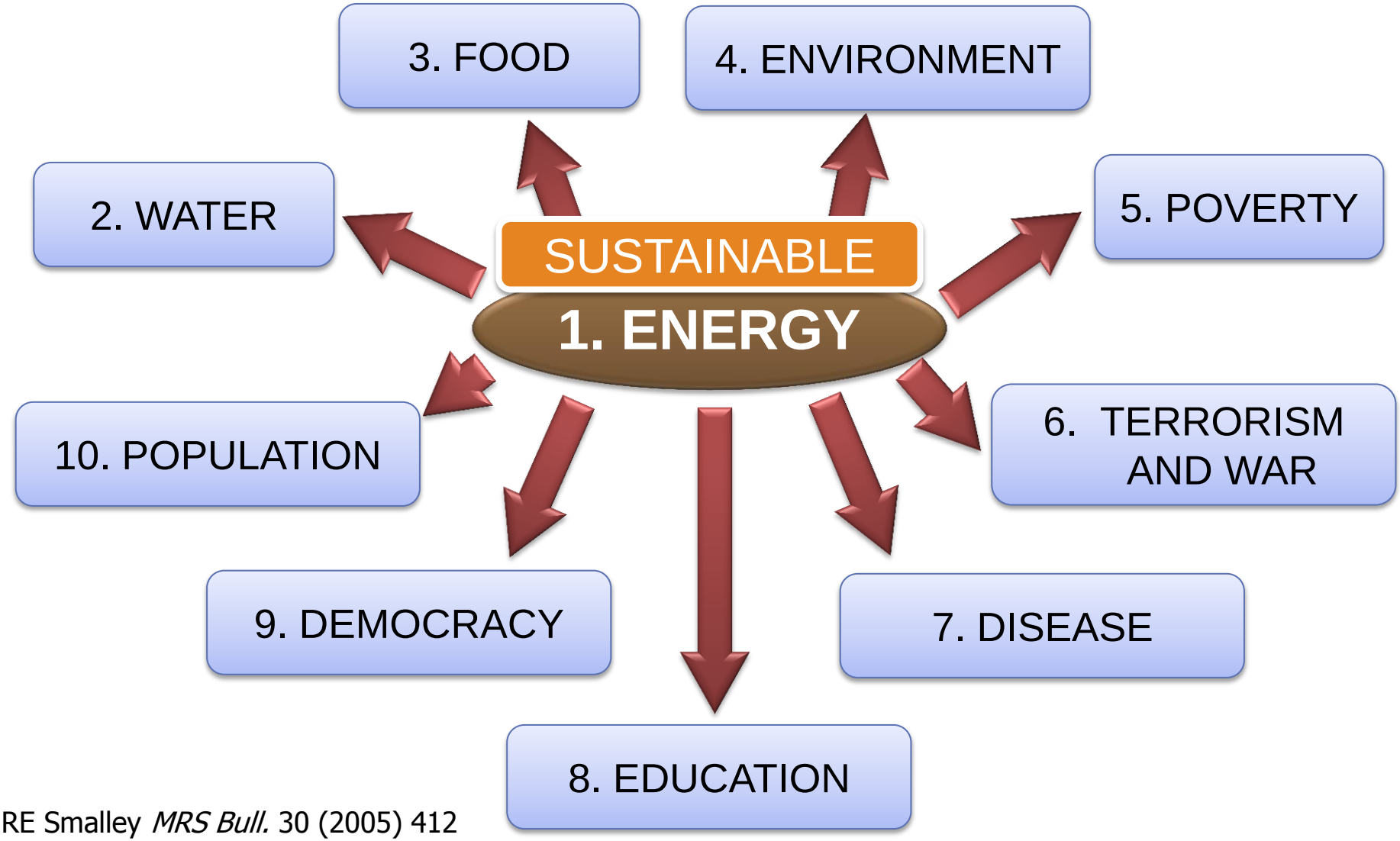
EXPO 2017 ASTANA
FUTURE ENERGY

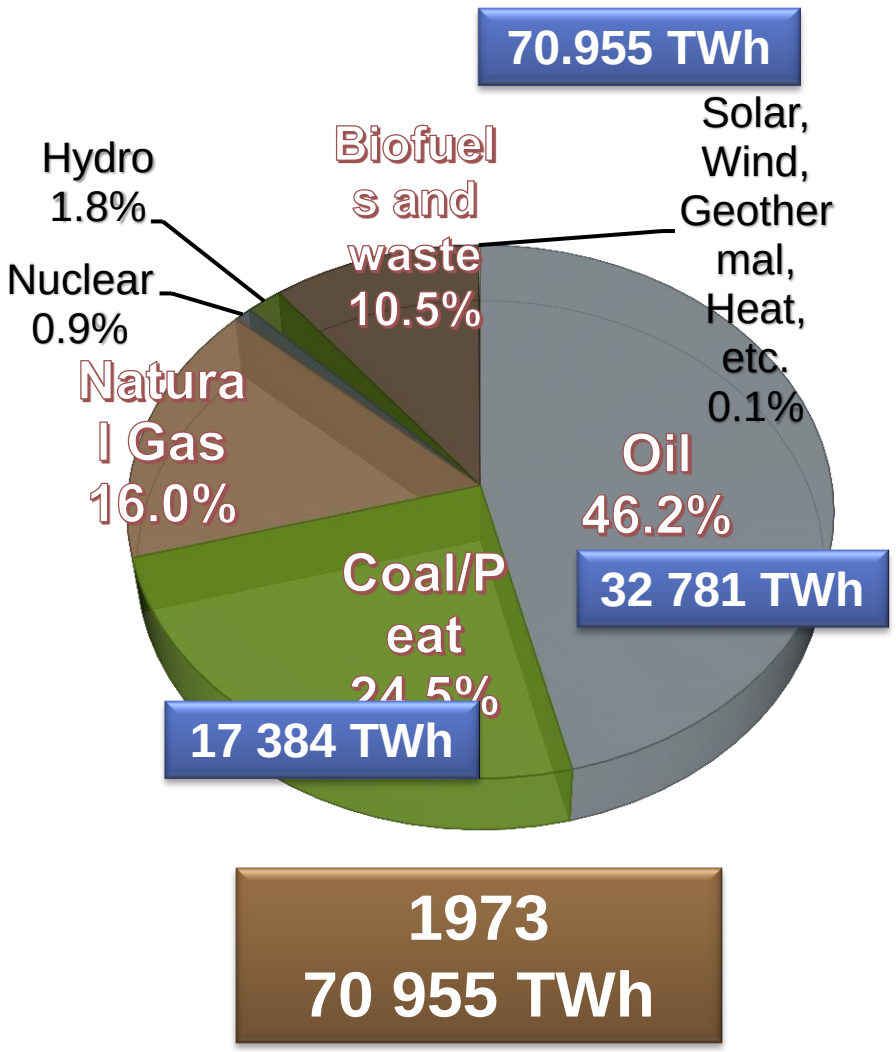
Swiss-Kazakh Joint International Seminar on
"Towards Smart Sustainable Cities – Integrated Approaches"
Nazarbayev University, 15-16 June 2017

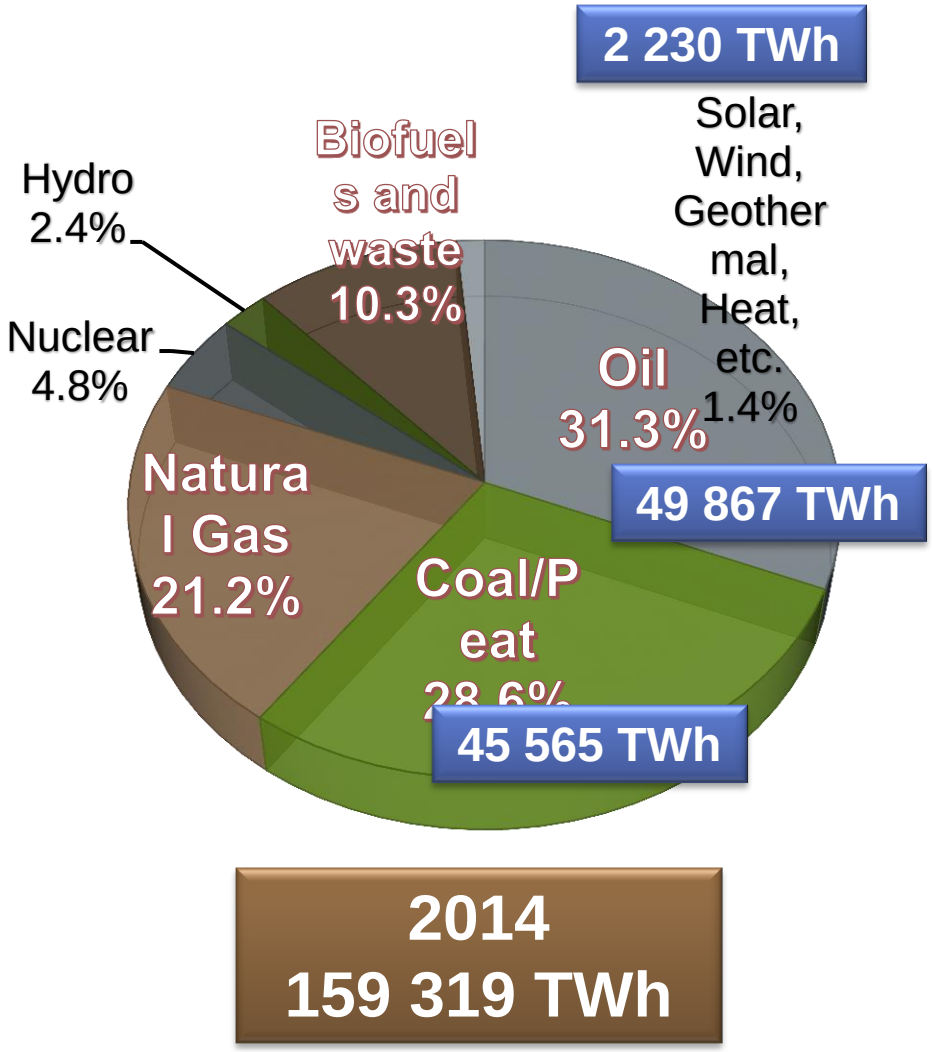
SOLUTION TO HUMANITY'S PROBLEMS
Richard Smalley (1996 Nobel Price in Chemistry)



RE Smalley *MRS Bull.* 30 (2005) 412

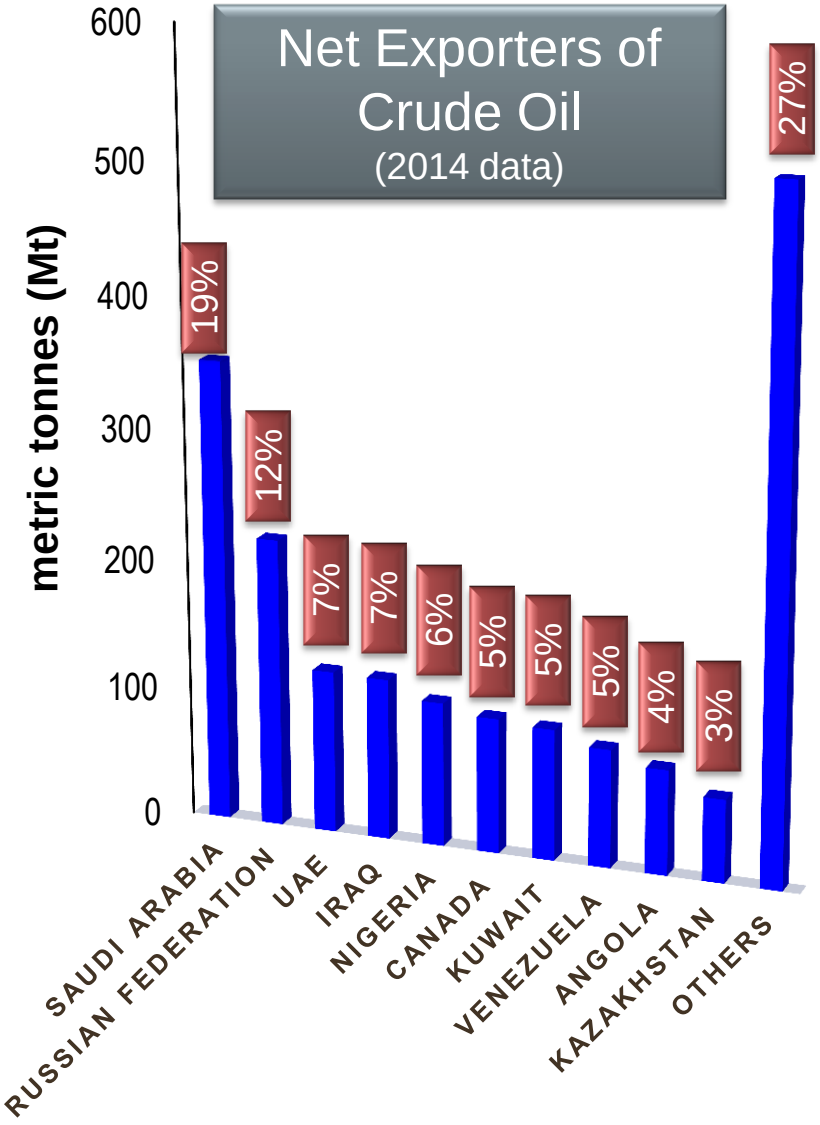
Fuel shares of the world total primary energy supply 1973 vs. 2014

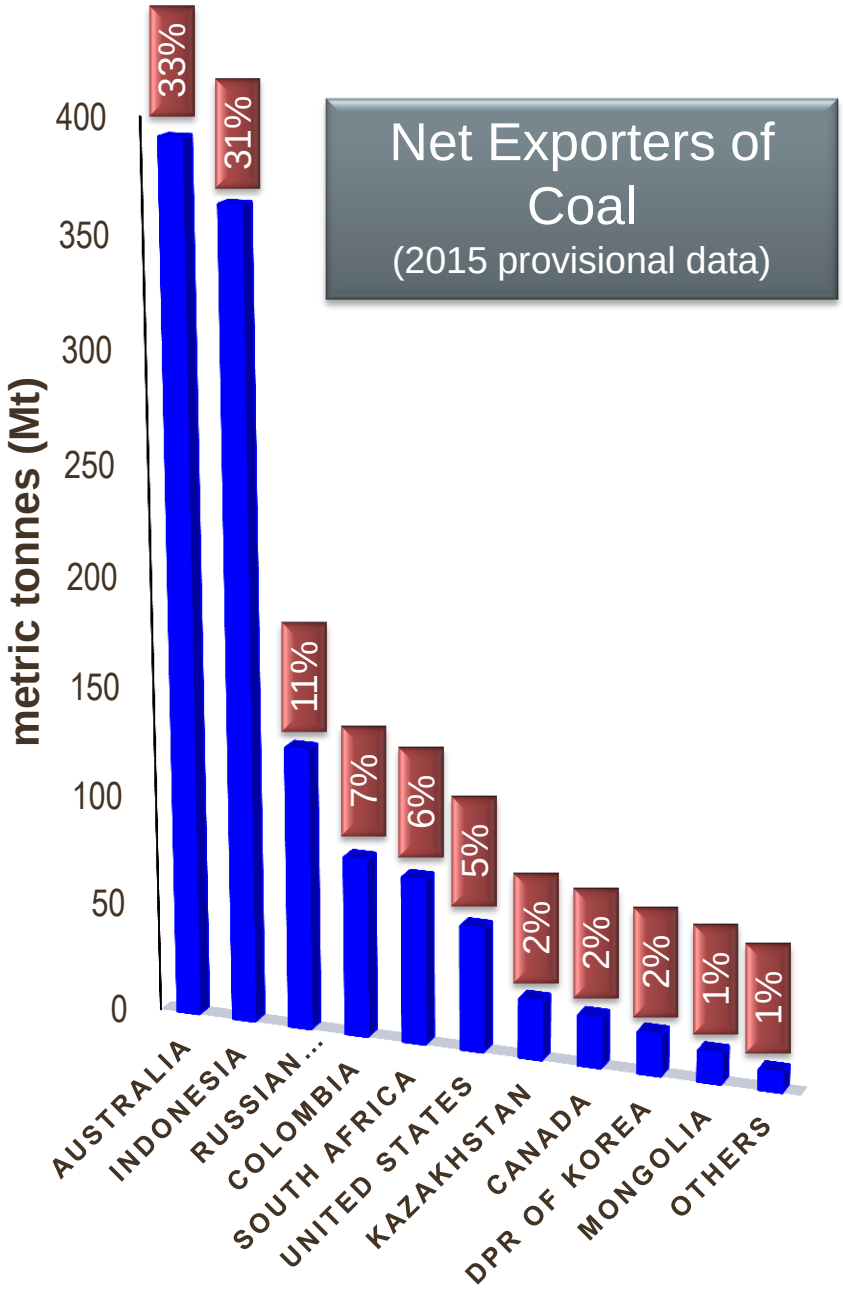




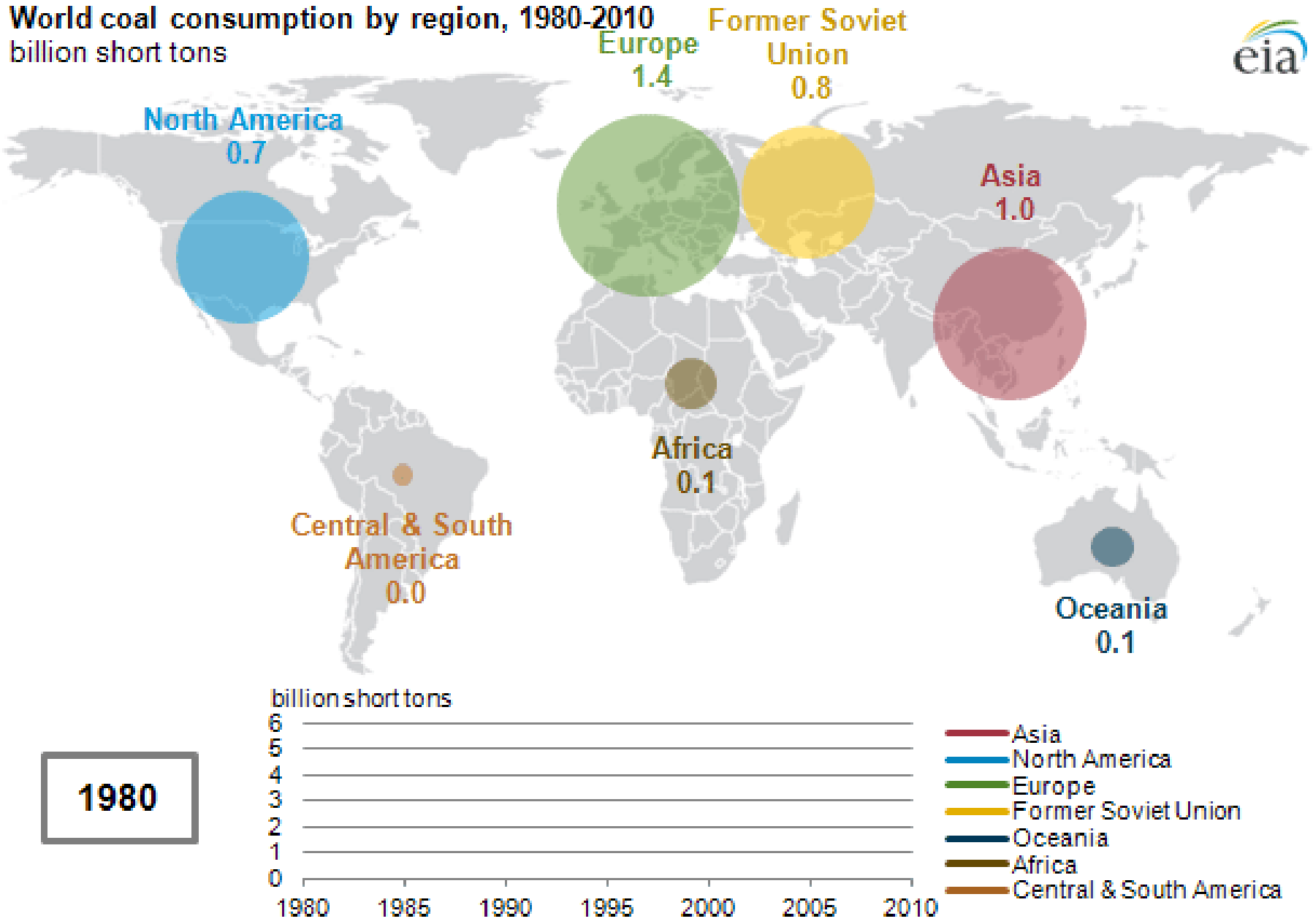
(Million tonnes of oil equivalent, Mtoe (1 Mtoe = 11.63 TWh)

https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf



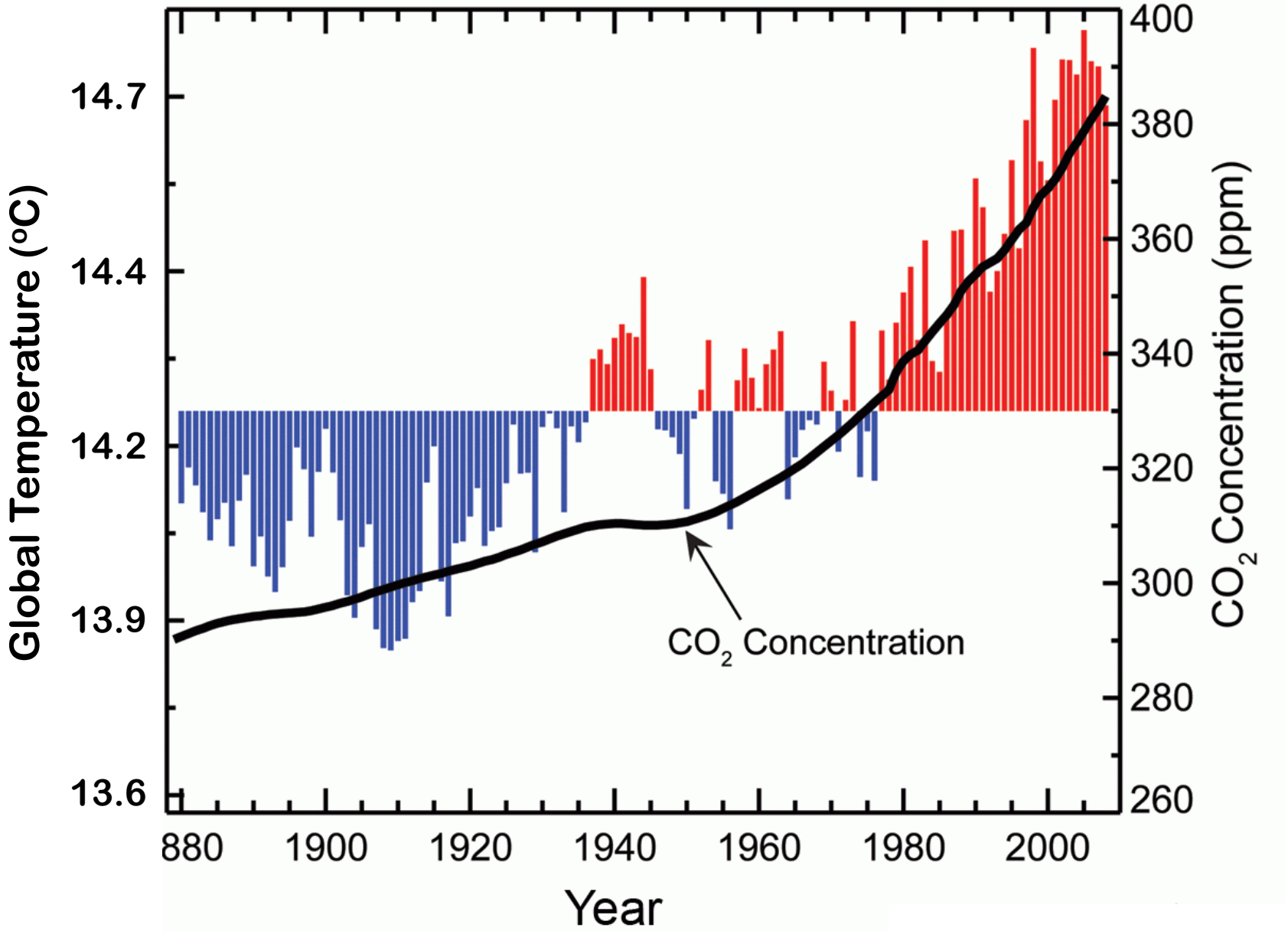


https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf



https://www.eia.gov/todayinenergy/detail.cfm?id=4390

CO_2 concentration versus Global Temperature



The Energy Revolution

TERAWATT CHALLENGE

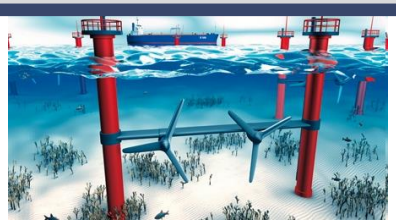
2014: 16 TW → **~4X** → **2050: 60 TW**

THE SOLUTION: RENEWABLE ENERGIES

Wind

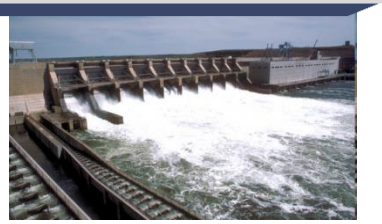
2–4 TW extractable

Ocean Current/Tides



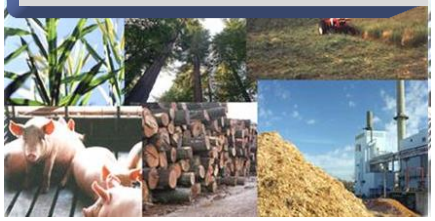
2 TW gross

Hydroelectric



1.2 TW technically feasible

Biomass



5–7 TW gross all cultivatable land not used for food

Geothermal

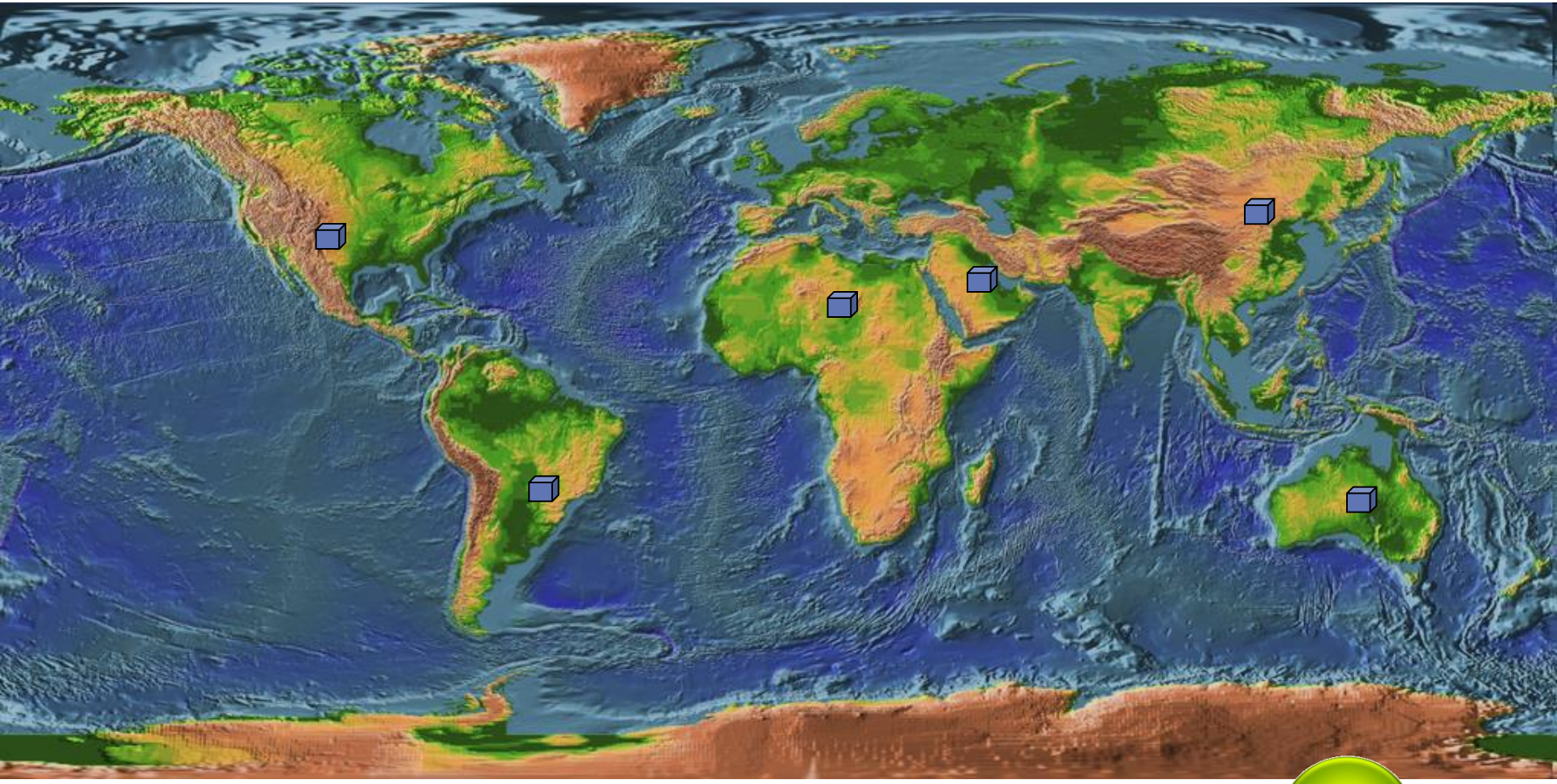
1.9 TW

Solar

1.7 x 10^5 TW at Earth surface
600 TW practical

Nate Lewis http://nsl.caltech.edu/energy

Solar cells land area requirements

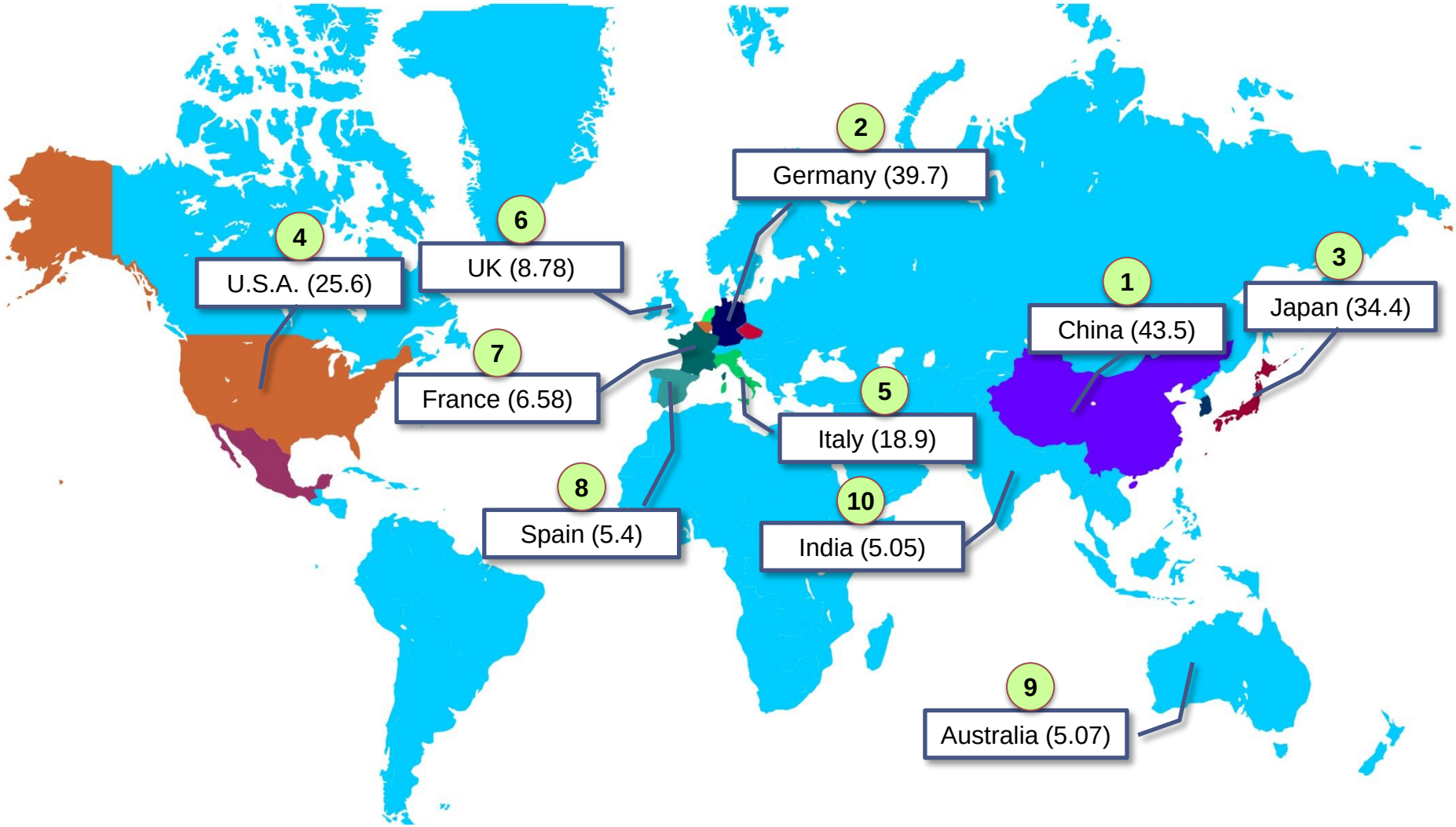


- 100 km^2
- Solar cells with 10% efficiency can create 10 TW of energy

Total: 60 TW

RE Smalley *MRS Bull.* 30 (2005) 412

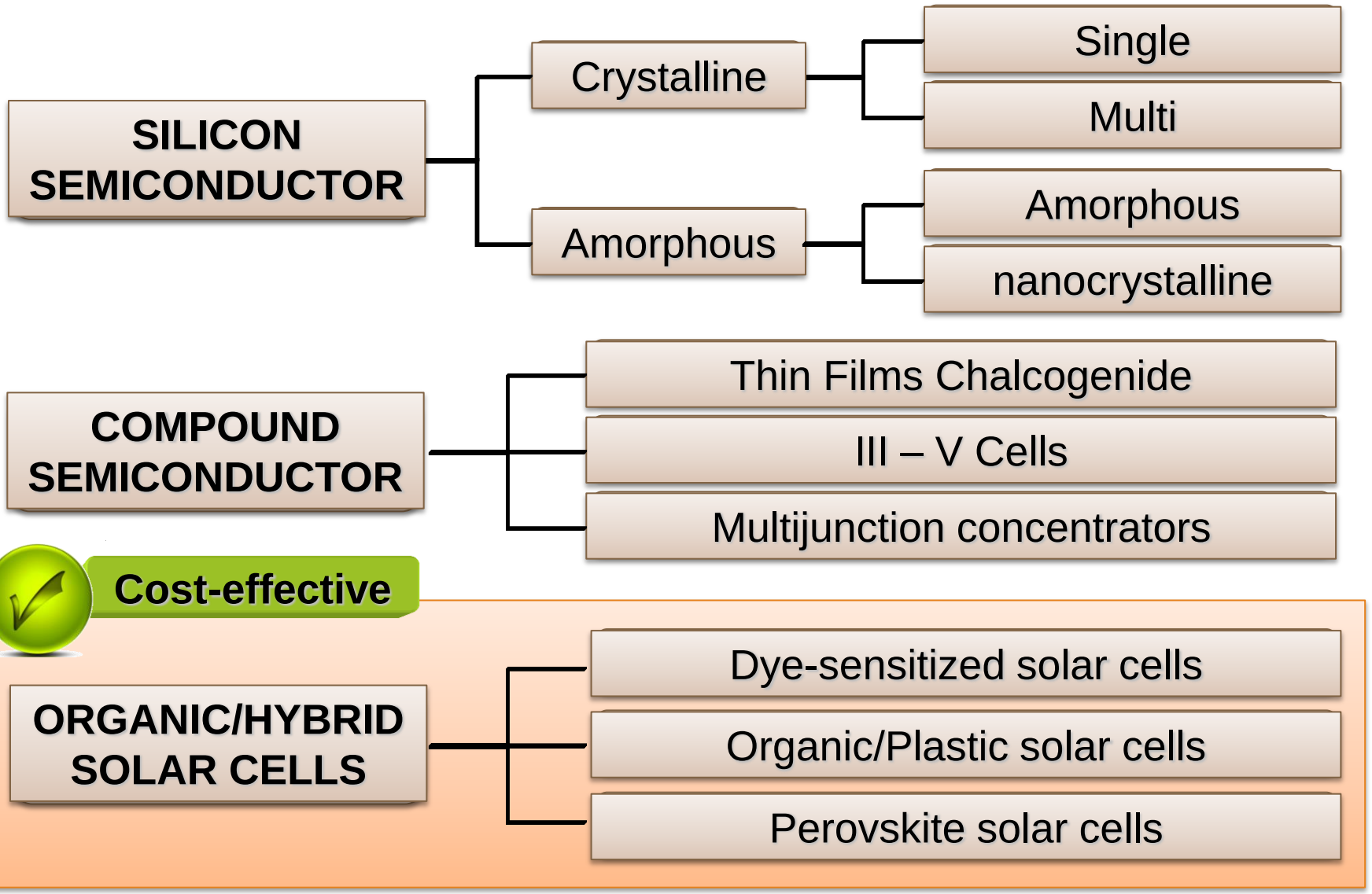
Top 10 Countries with installed PV Power (2015)



All data in gigawatts (GW)
IEA Report (22 April 2016)

http://www.iea-pvps.org/fileadmin/dam/public/report/PICS/IEA-PVPS_-__A_Snapshot_of_Global_PV_-_1992-2015_-_Final_2_02.pdf

Types of Solar Cells



Largest concentrated solar plant

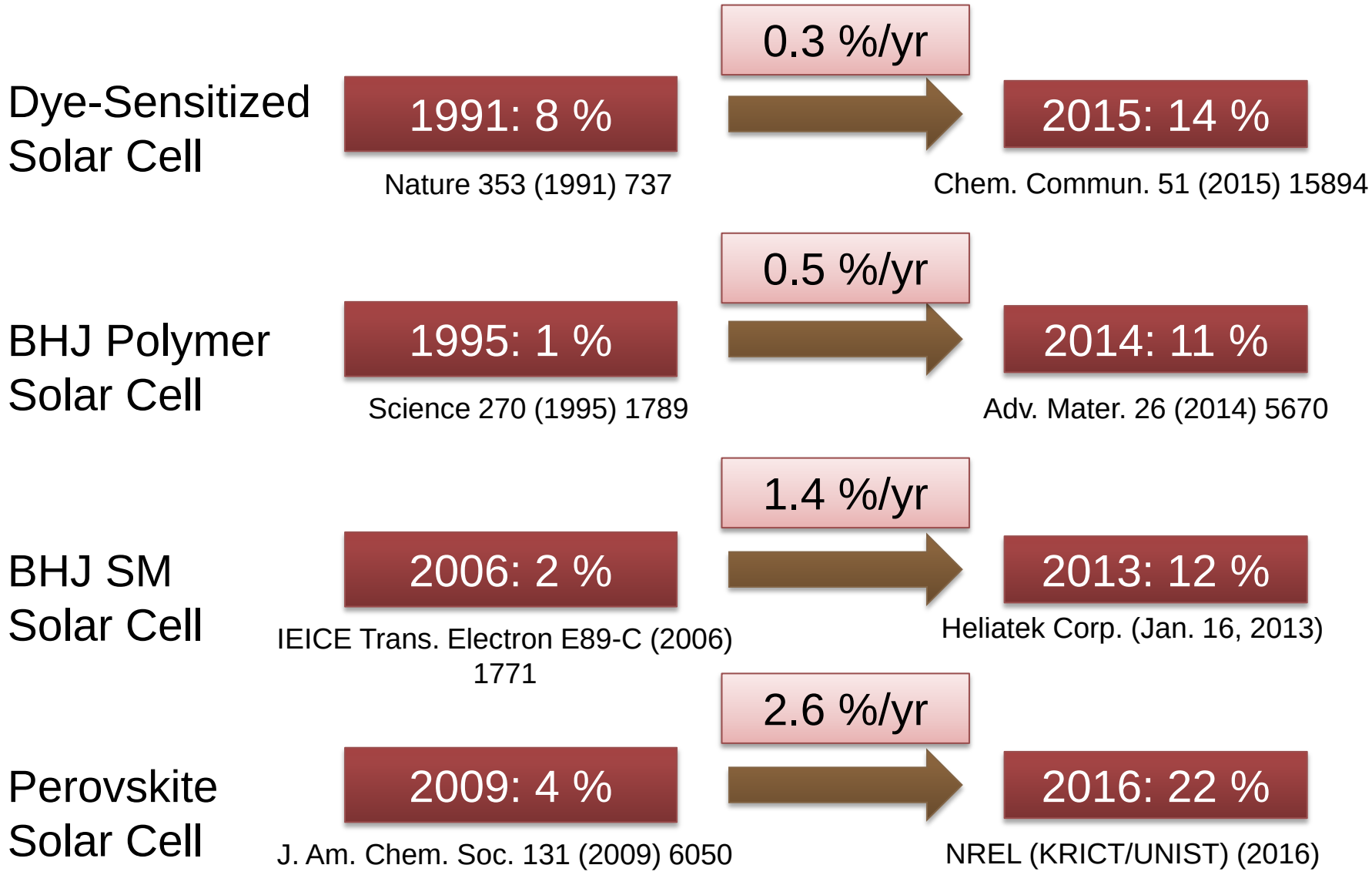
- MA- Noor Ouarzazate Concentrated Solar Power Project
  - Ouarzazate, Morocco
  - 2000 MW of solar power generation capacity by 2020
    - 18 % national electric generation
  - 30 km^2

Largest PV solar plant

- Adani Green Energy (Kamuthi, Tamil Nadu, India)
  - 648 MW covers and area of 10 km^2
    - Topaz Solar Farm in California, USA (550 MW)
  - Produce enough electricity to power about 150,000 homes
- Goal of Adani Group: construct 10,000 MW of solar power by 2022

https://goo.gl/V4LTO2 (Accessed May 15, 2017)

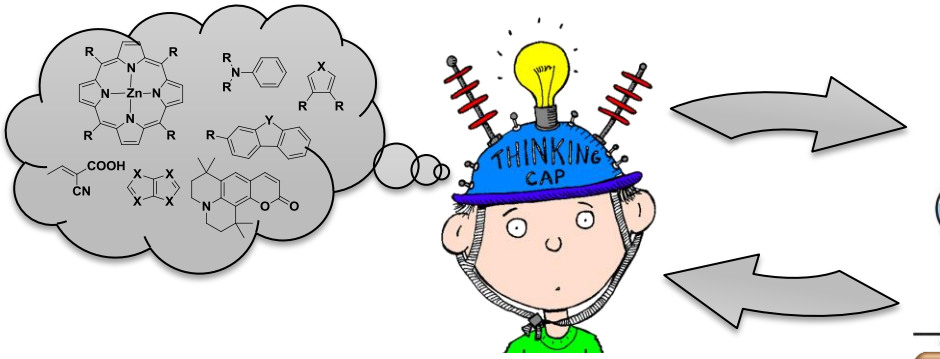
PV Solar Cells through the years

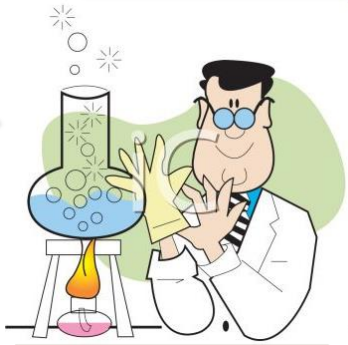


PARADIGM SHIFT

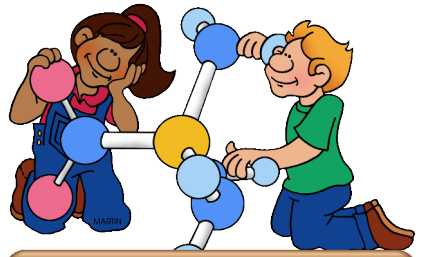
CONVENTIONAL APPROACH

- Expensive
- Time-consuming





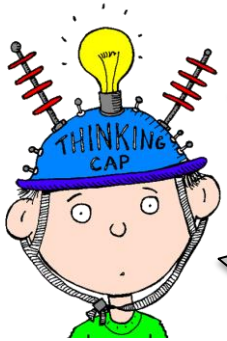
EXPERIMENTAL



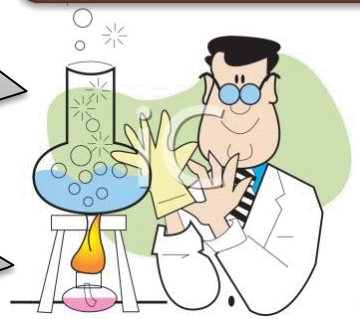
FUNCTIONAL MATERIALS

THEORETICAL APPROACH

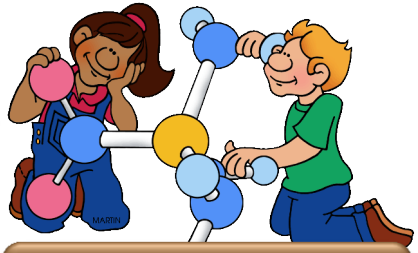
- Cost-saving
- Faster design process



THEORETICAL



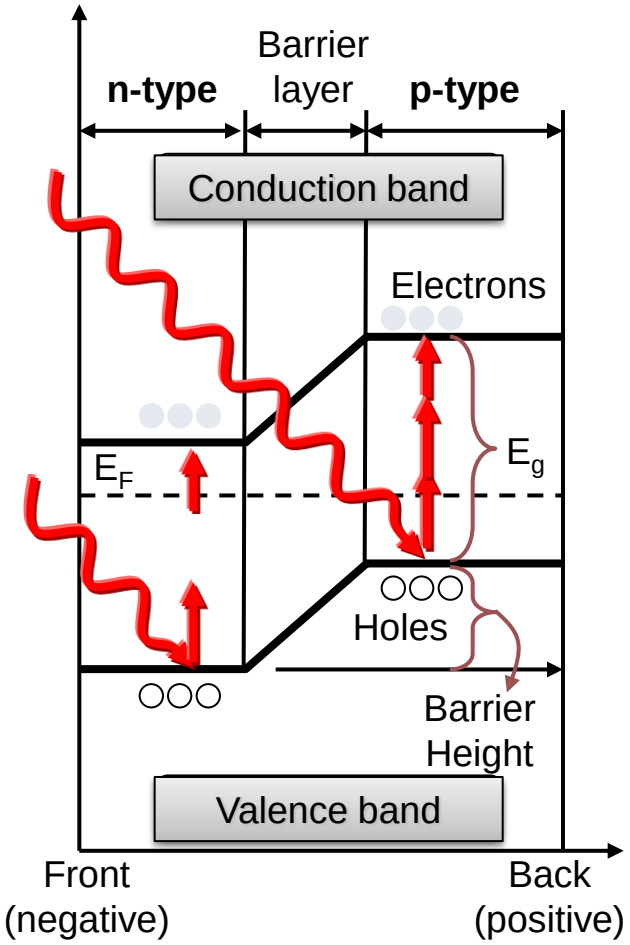
EXPERIMENTAL



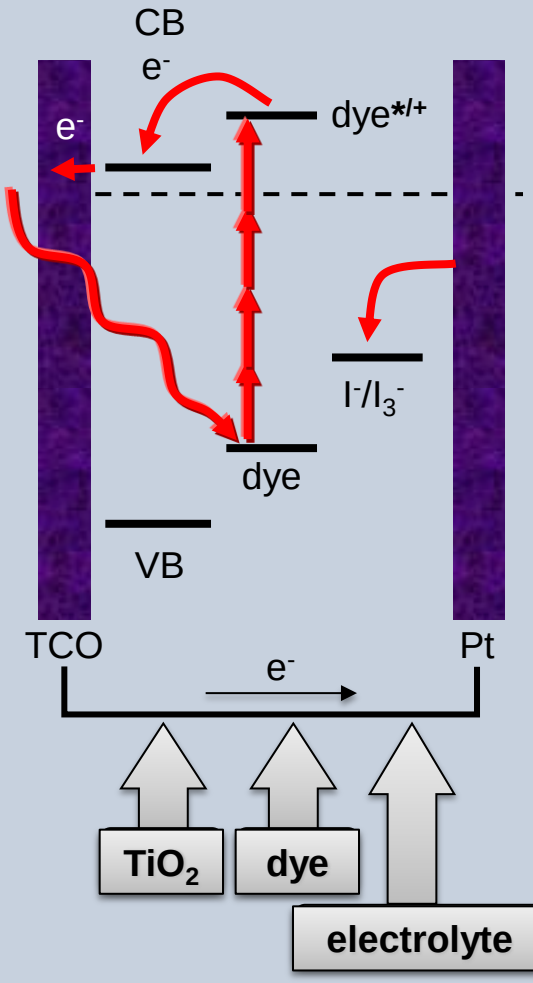
FUNCTIONAL MATERIALS

COMPARISION OF THE OPERATING PRINCIPLES OF SOLAR CELLS

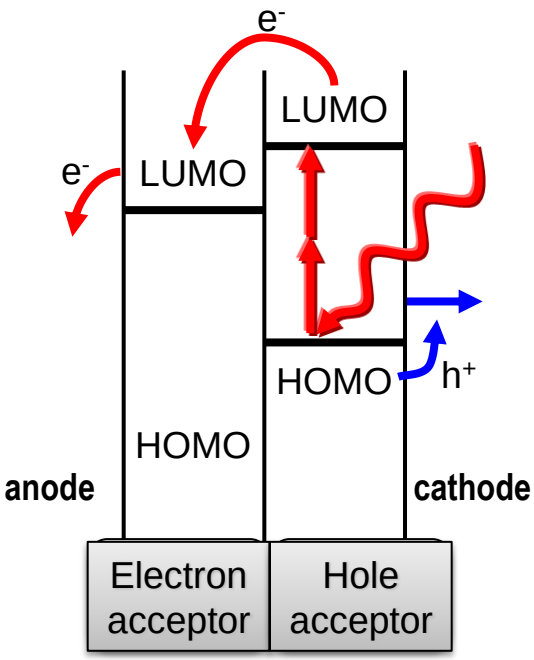
Silicon PV cells

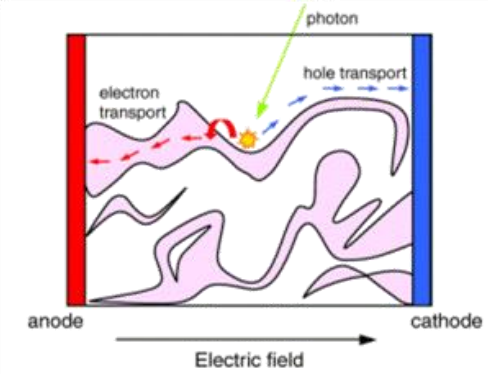


Dye-Sensitized Solar cells

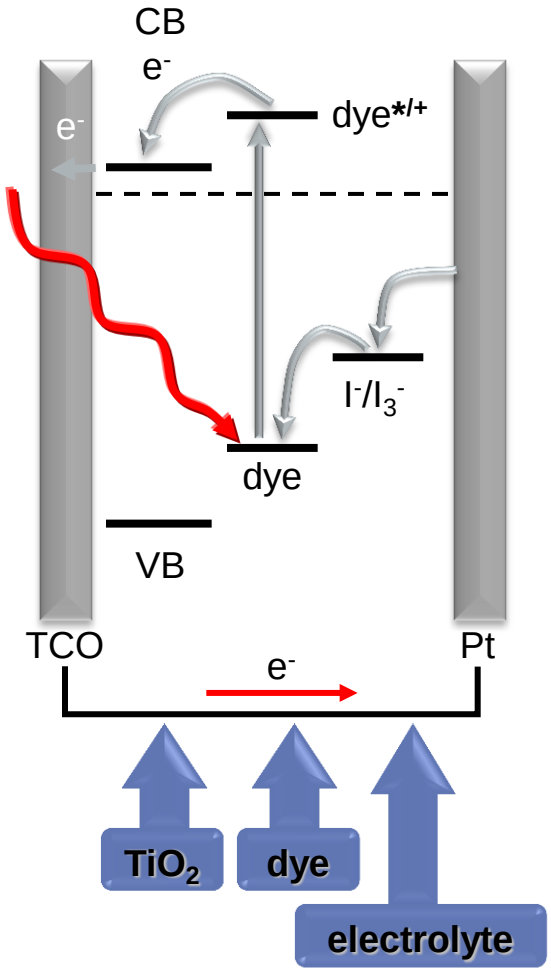


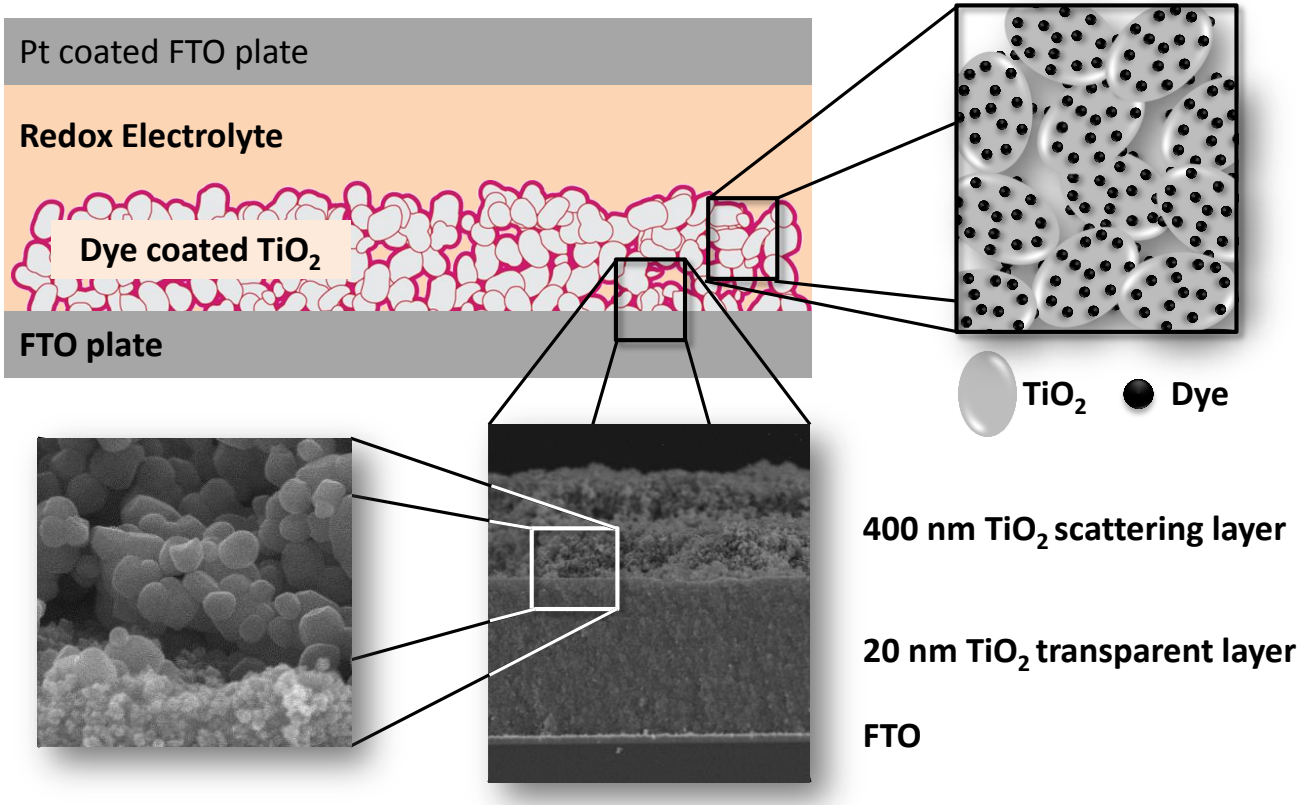
Organic Solar cells





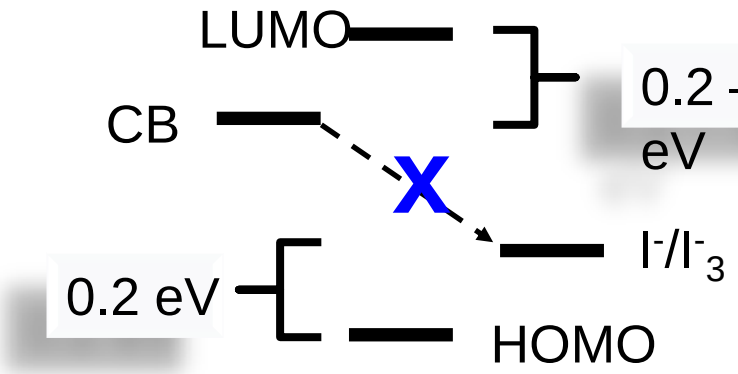
Principles of DSSCs

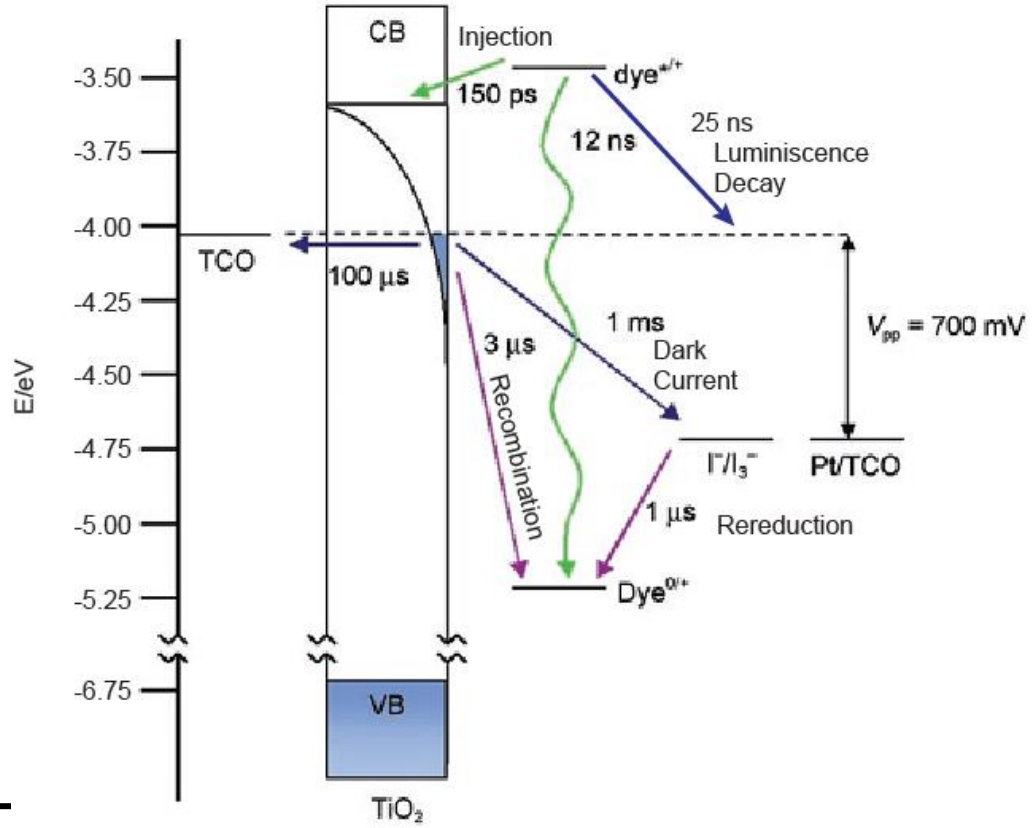




Requirements of Sensitizers

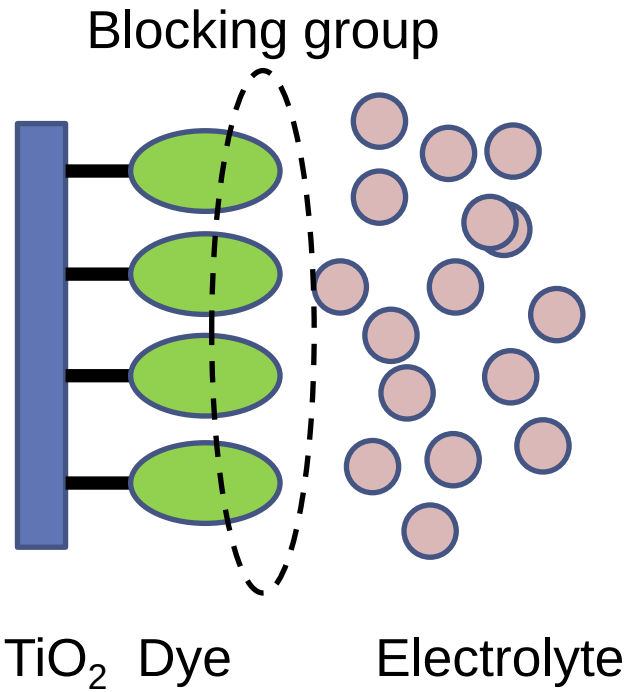
- It should posses suitable ground- and excited-state redox properties

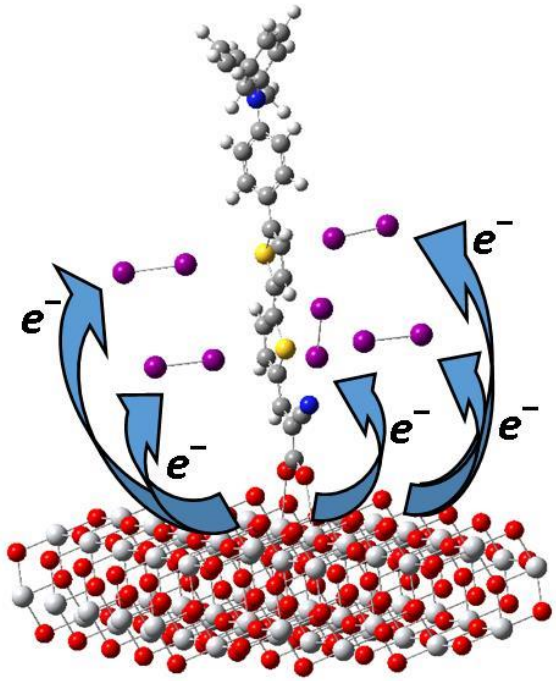




Requirements of Sensitizers

- It should properly block the redox couple from interacting with the surface of the semiconductor to prevent electron recombination

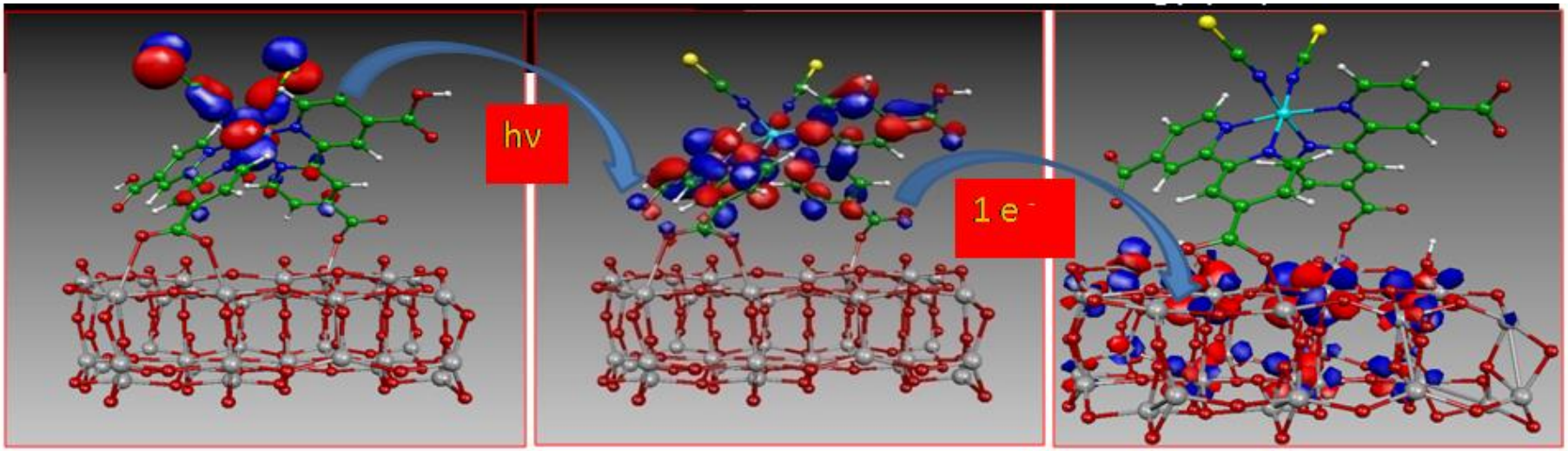




- It should prevent the stable formation of dye-iodine complex in order not to disrupt dye regeneration process

Requirements of Sensitizers

- It should be efficient in charge separation
- It must be firmly grafted to the semiconductor oxide surface and inject electrons into the conduction band with a quantum yield of unity



MdK. Nazeeruddin, F De Angelis, S Fantacci. M Grätzel *J. Am. Chem. Soc.* 127 (2005) 16845

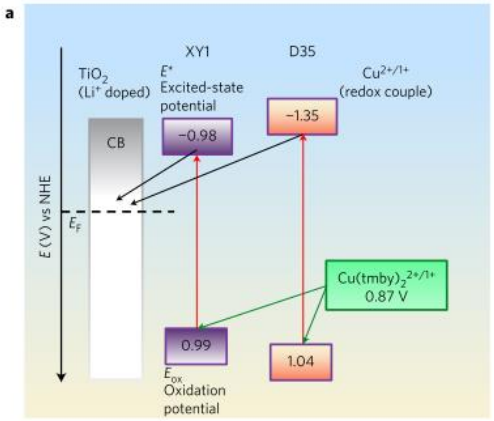
- It should exhibit thermal and photochemical stability

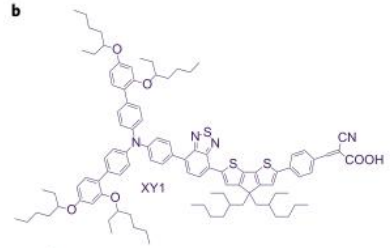
nature photonics

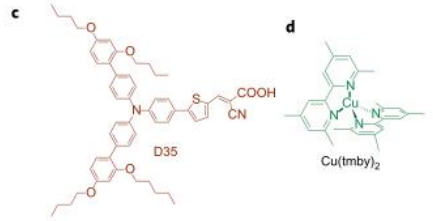
Vol. 11 (June 2017) pp. 372 - 379

Dye-sensitized solar cells for efficient power generation under ambient lighting

M. Freitag, J. teuscher, Y. Saygili, X. Zhang, F. Giordano, P. Liska, J. Hua, S.M. Zakeruddin, J.E. Moser, M. Grätzel, A. Hagfeldt







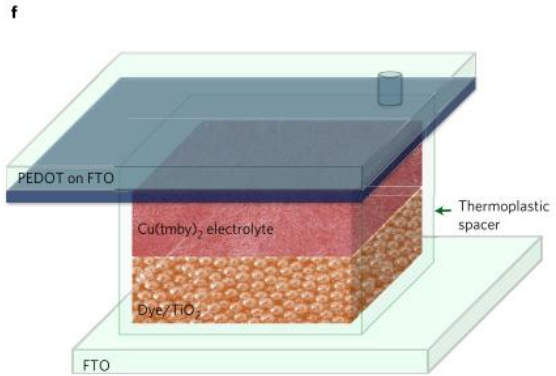


Table 1 | Photovoltaic metrics for DSCs and GaAs solar cells for indoor-light sources at 200 lux and 1,000 lux.

Solar cell	Light source	Light intensity (lux)	J_{sc} (μA cm^{-2})	V_{oc} (mV)	FF (%)	P_{in} (μW cm^{-2})	P_{out} (μW cm^{-2})	PCE (%)
DSC*	Osram Warm White 930	200	27.2	732.0	0.79	61.3	15.6	25.5
DSC†		200	24.8	700.0	0.79	61.3	13.7	22.3
DSC*		1,000	138.0	797.0	0.80	306.6	88.5	28.9
DSC†		1,000	137.2	766.0	0.80	306.6	84.1	27.4
Flexi-GaAs (Alta)	Osram Warm White 827	200	20.1	870.0	0.75	70.6	13.1	18.6
Flexi-GaAs (Alta)		1,000	99.0	940.0	0.80	354.0	74.5	21.0

*Acetonitrile-based electrolyte. †Propionitrile-based electrolyte. The PCEs for the solar cells are determined from equation (2). Flexi-GaAs solar cells are from Alta Devices measured at GCell with a configuration of six cells of area 8.33 cm^2 in parallel and in series connected to a mini-module of size 50 cm^2.

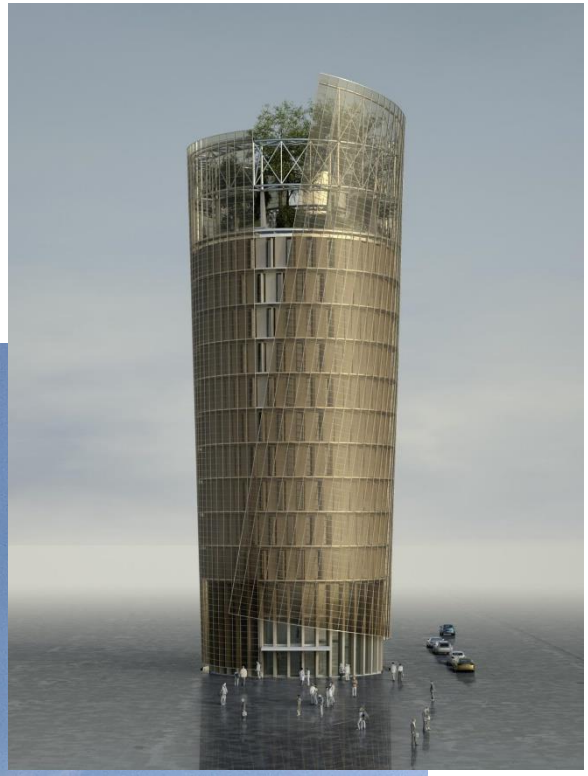
SwissTech Convention Center
DSSC panels made by Solaronix

http://cen.acs.org/articles/94/i18/future-low-cost-solar-cells.html

Graz Science Tower in Austria

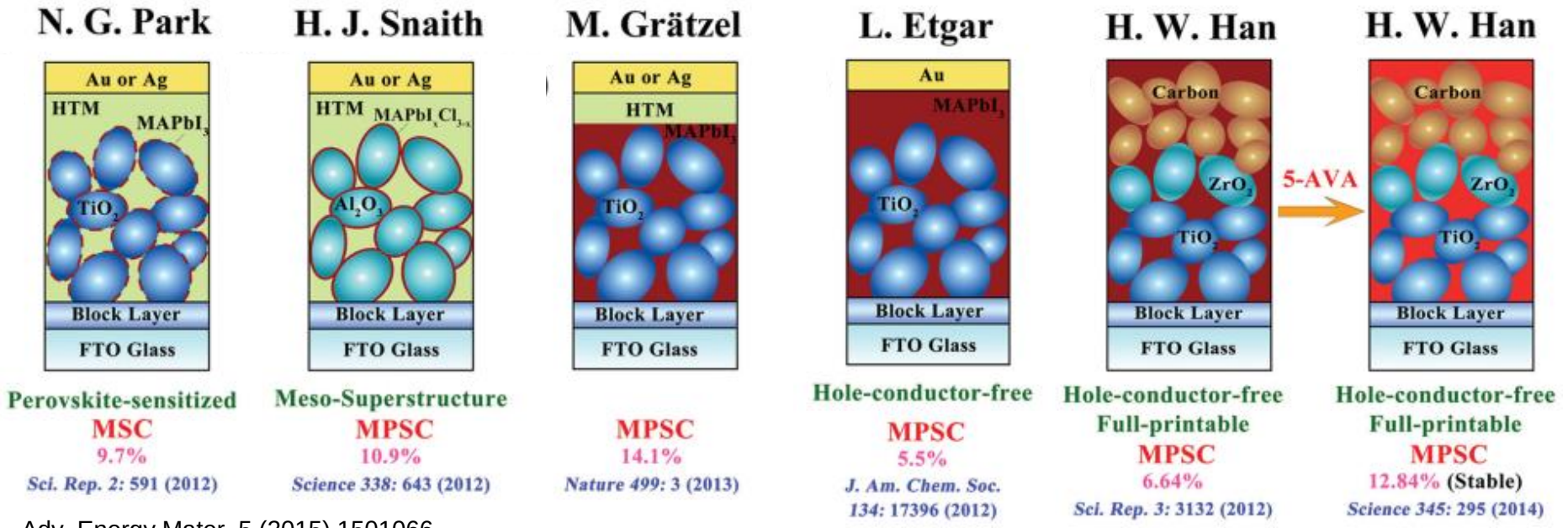
"Urban building blocks": self sufficient in energy

- wrapped with translucent green and orange DSSCs manufactured by the Swiss company H.Glass
- estimated completion date: October, 2017

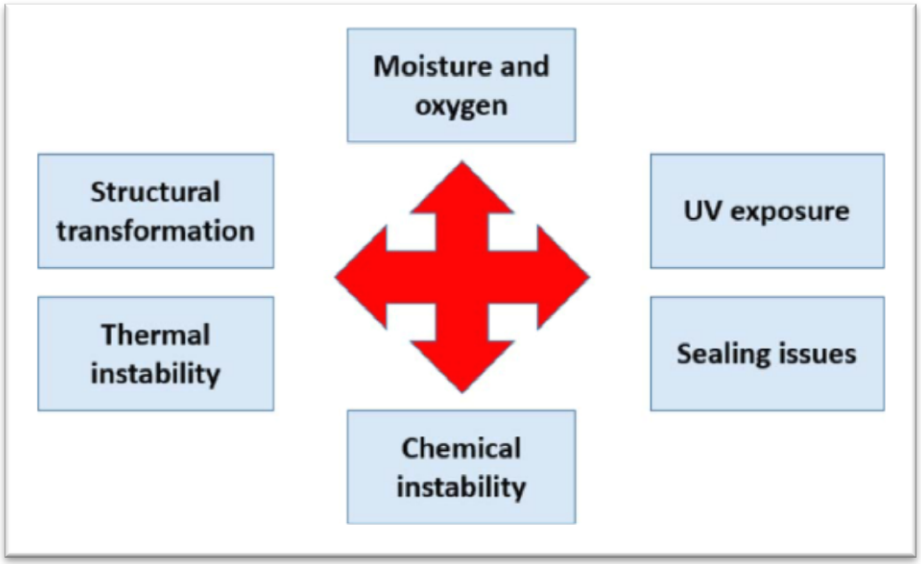


http://science-tower.at/

Historical Evolution of Perovskite configuration



Adv. Energy Mater. 5 (2015) 1501066



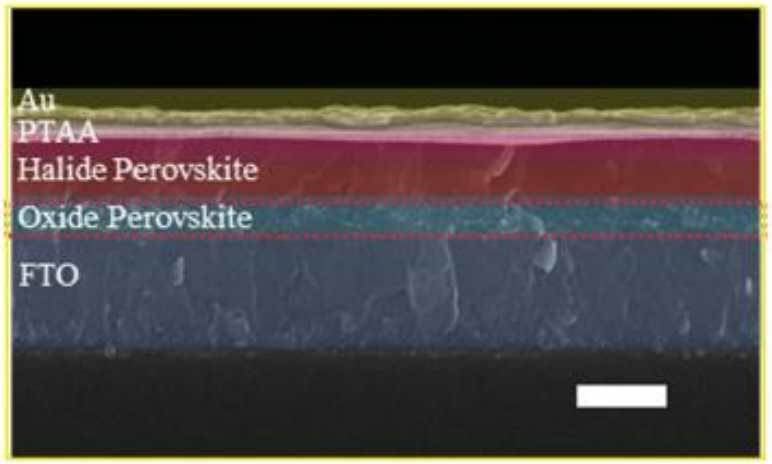
Degradation issues of PeSCs

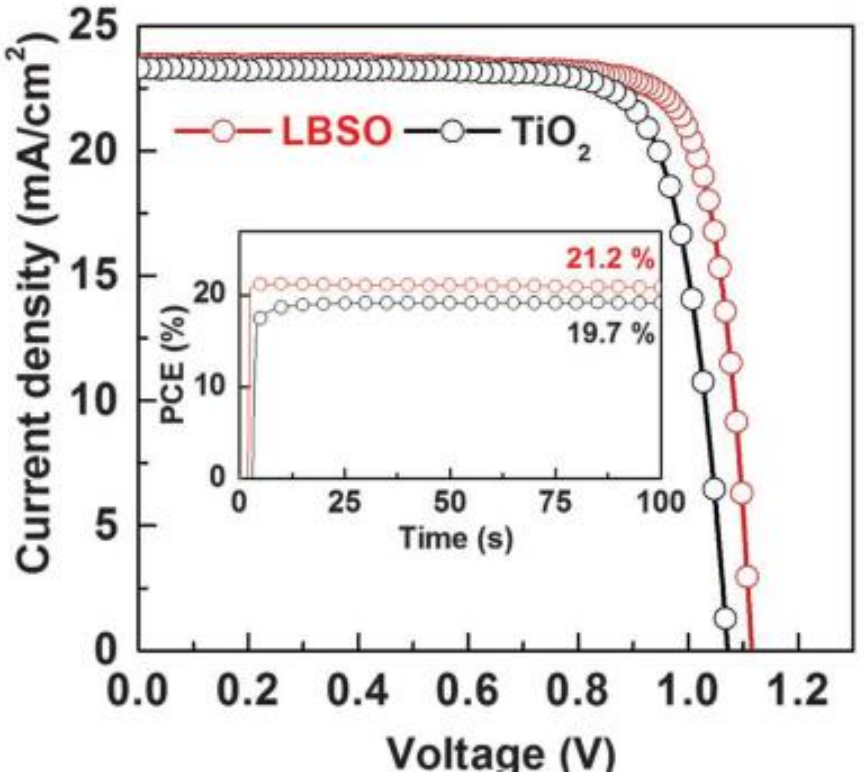
Renewable Sustainable Energy Rev. 77 (2017) 131-146

Science
14 April 2017
Vol. 356
pp. 167 - 171

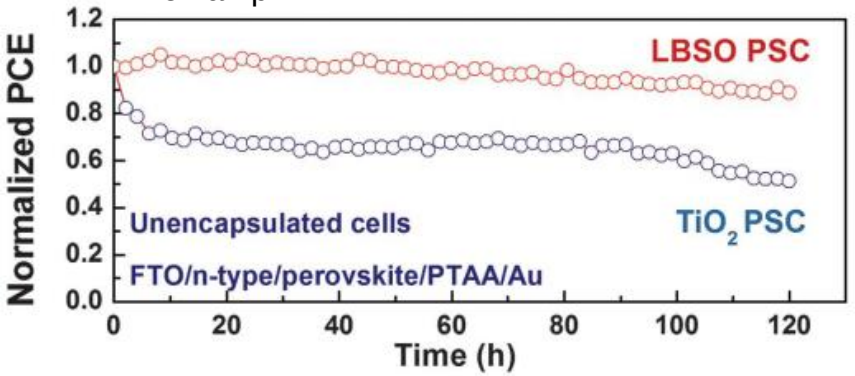
Colloidally prepared La-doped $BaSnO_3$ electrodes for efficient, photostable perovskite solar cells

Seong Sik Shin,[1,2] Eun Joo Yeom,[1] Woon Seok Yang,[3] Seyoon Hur,[4] Min Gyu Kim,[5] Jino Im,[1] Jangwon Seo,[1] Jun Hong Noh,[1,6]* Sang Il Seok[1,3]*

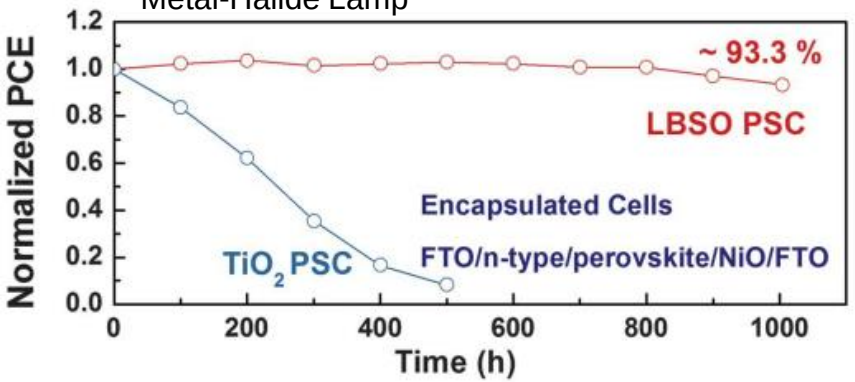




Xe Lamp



Metal-Halide Lamp



Commercialization phase

March 9, 2017

Solliance sets world record for roll-to-roll produced perovskite-based solar cells with a stabilized efficiency of 12,6%

"This breakthrough result paves the way towards an accelerated market introduction of this attractive new source of renewable energy."

PeSCs Commercialization

"Real commercialization of perovskite photovoltaics is unlikely to happen until the 2019–2021 time frame"

Tyler Ogden

Market analyst, Lux Research

The role of research especially in academe will continue to be an integral part of the development of a low-cost solar cell in many years to come.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