광전기화학 시스템 원리

Principles of Photoelectrochemical System

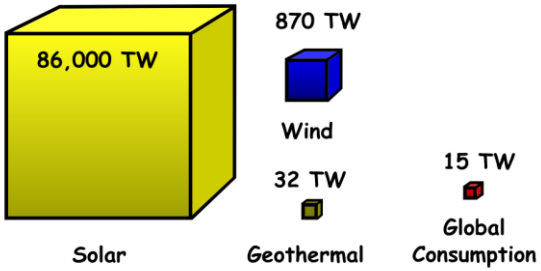
Uk Sim

Department of Materials Science & Engineering

Chonnam National University

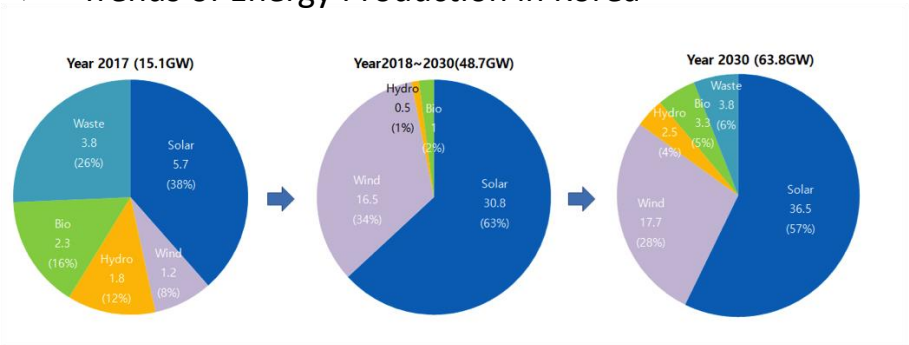
Solar Energy

➢ Solar Energy vs Global Consumption



- Global energy consumption is approximately 15 TW
- Solar energy is 86,000 TW, which is about 5,700 times greater that the consumption.
- About 99 times greater than wind energy, and about 2,687 times greater the geothermal energy

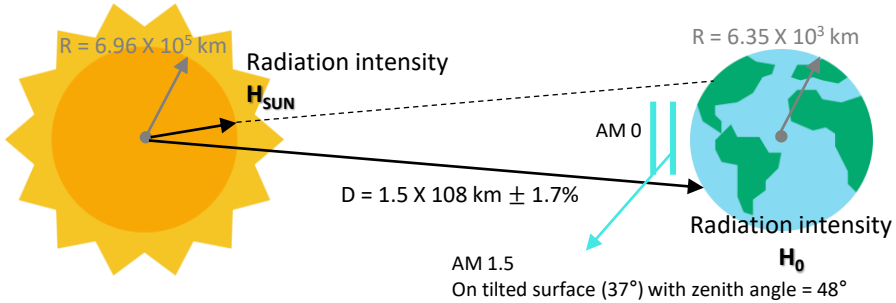
➢ Trends of Energy Production in Korea



South Korea's move towards renewables, Energy Transition, 2018

➢ Solar Irradiation and Air Mass 1.5

$$H_0 = \frac{R^2_{SUN}}{D^2} H_{SUN}$$



- *Solar irradiance (H_0) ; power density*

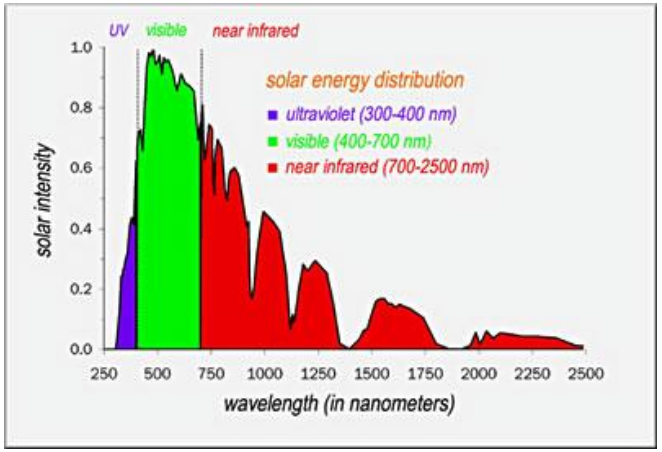
  The amount of power radiated from the sun transmitted from a point as far away as D
- *H_{SUN} : 5.961 X 10^7 W/m^2*
- *Calculated solar irradiance at the Earth= 1.353 kW/m^2*
- *Air Mass zero (AM0) takes a value of 1.353kW/m^2*

  (AM : effect of radiant power density at Earth)
- ***Average spectrum = AM 1.5***

Solar Water Splitting

Limitations

- Limited Utilization of Solar Spectrum



$$\frac{1240\ \text{nm}}{E_g} = \lambda\ \text{nm}$$

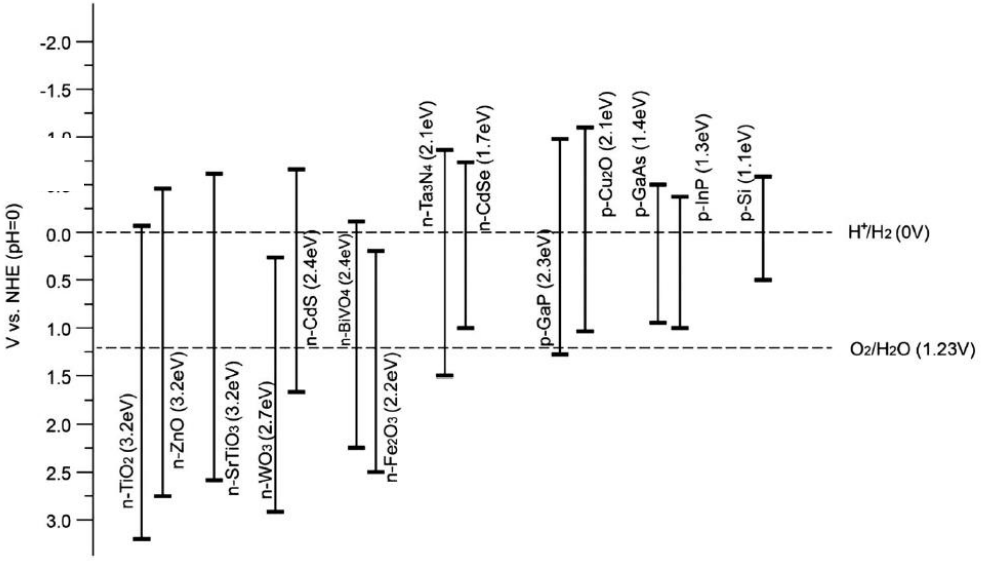
Visible Range shows higher intensity
Energy-wise, NIR range takes up 50%

Water Splitting potential (1.23 eV) = 1008 nm;
up to some part of NIR

- Recombination Rate vs Light Absorption

With small bandgap,

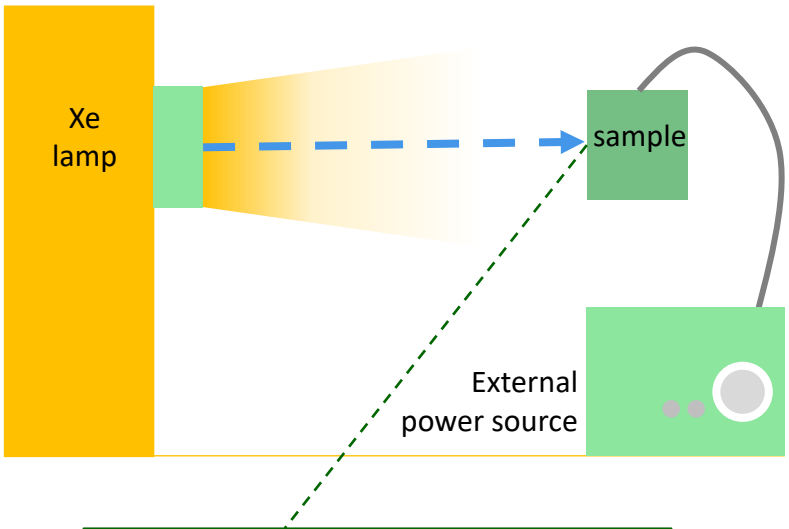
- wider range of solar spectrum can be utilized
- high recombination rates which lowers the charge generation rate



Bandgap between 1.5 ~ 2.5 eV is recommended for Water Splitting
However, utilization of Solar Irradiation is limited

Solar Energy

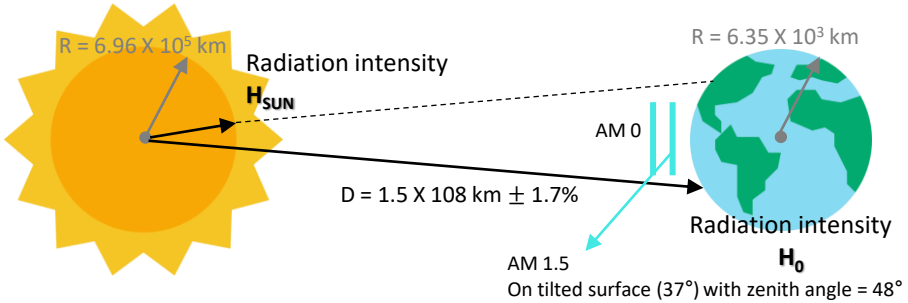
- Photoelectrochemical (PEC) system



light intensity of **100 mW/cm²**
(**Air Mass 1.5** Global condition glass filter)

- Air Mass 1.5?

$$H_0 = \frac{R^2_{SUN}}{D^2} H_{SUN}$$



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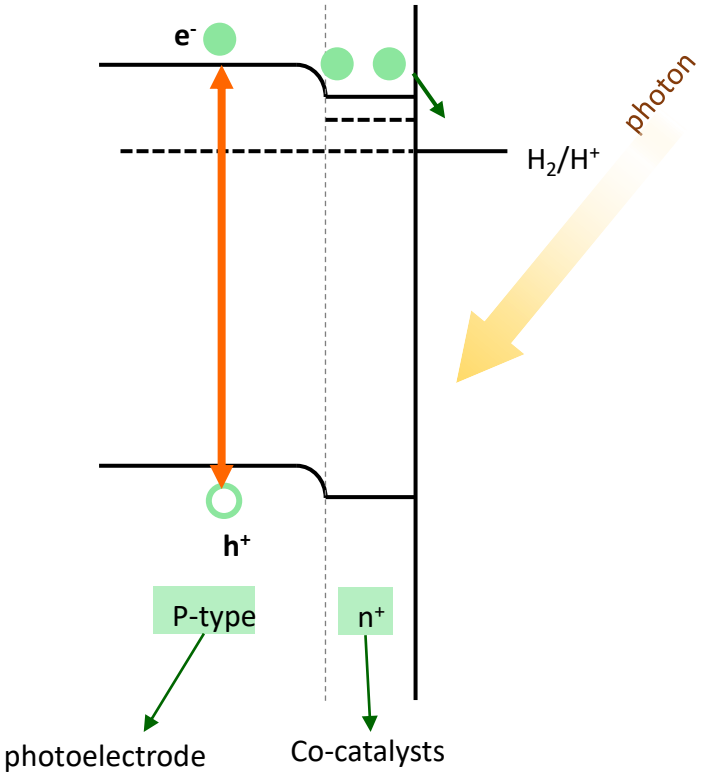
Photogeneration

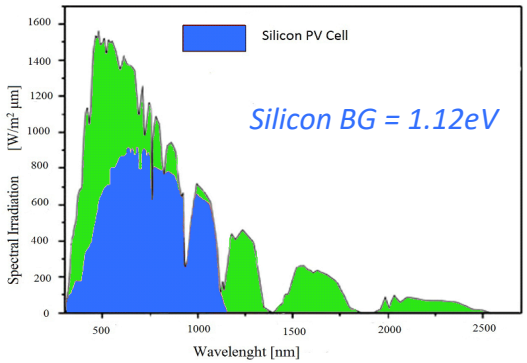
light intensity of **100 mW/cm²**
(**Air Mass 1.5** Global condition glass filter)



① *Appropriate bandgap for solar spectrum*

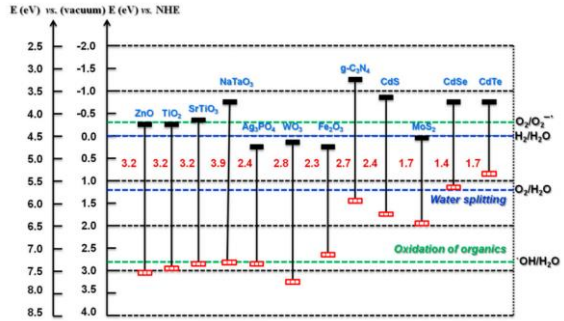
② *High electron mobility*

③ *Low recombination rate*



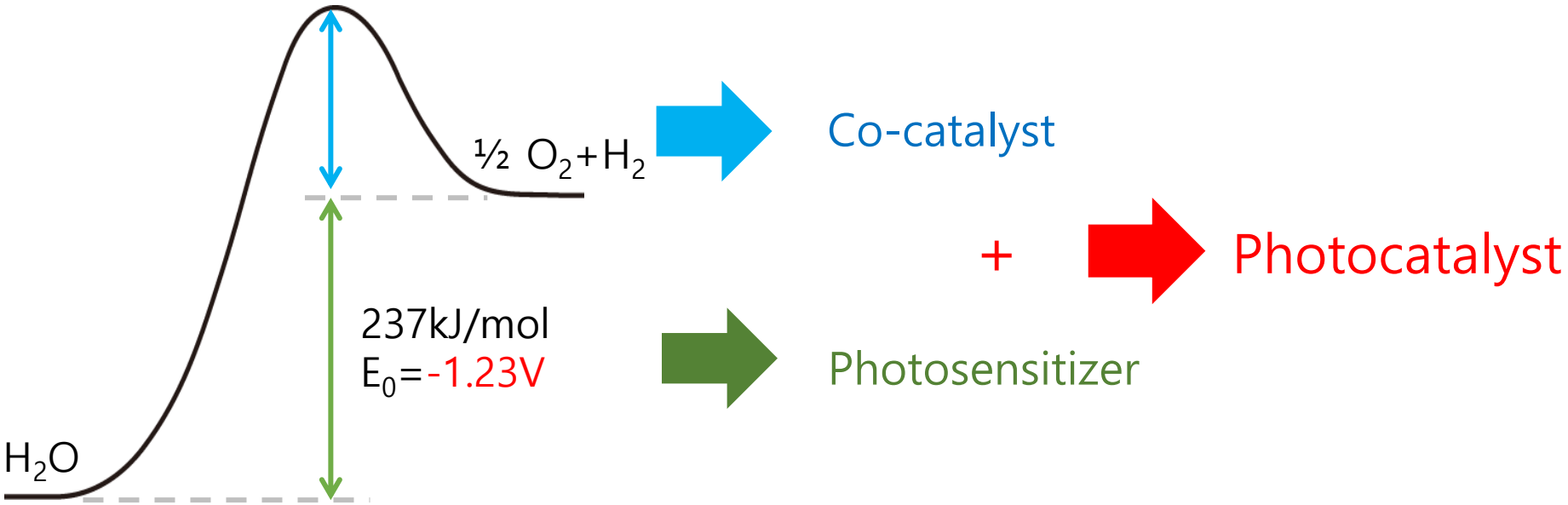
$$\frac{1240\ \text{nm}}{E_g} = \lambda\ \text{nm}$$

As the bandgap increases, the absorbable wavelength band shifts to the UV region

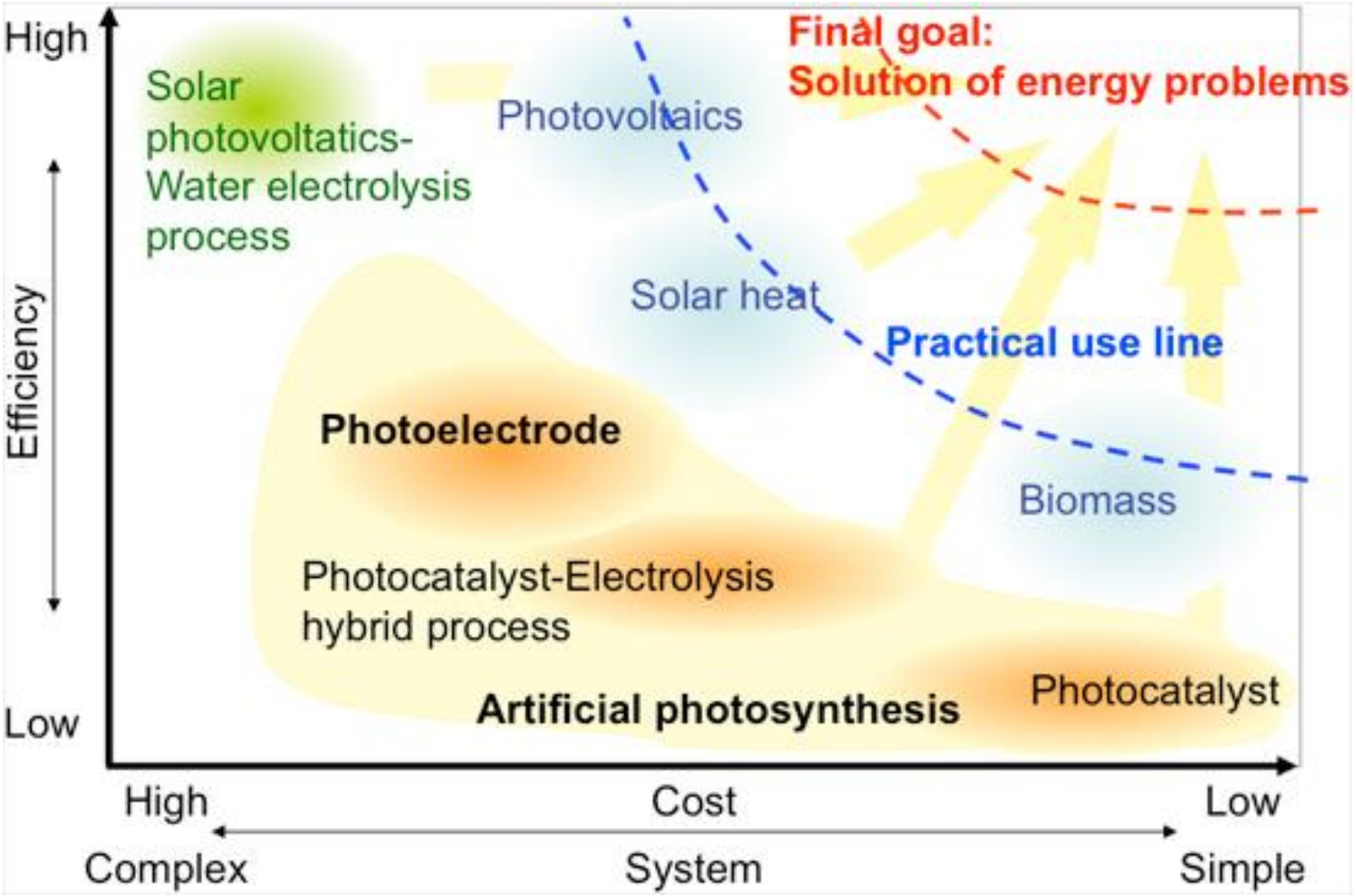


The material with a bandgap matching the redox potential window where water splitting occurs should be well chosen.

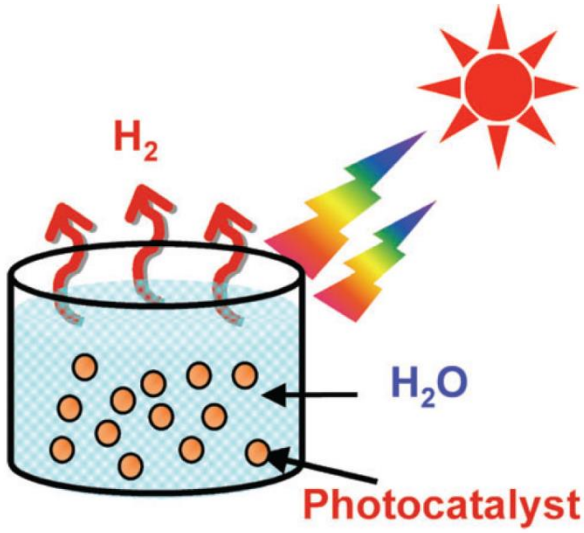
What is Photocatalyst?

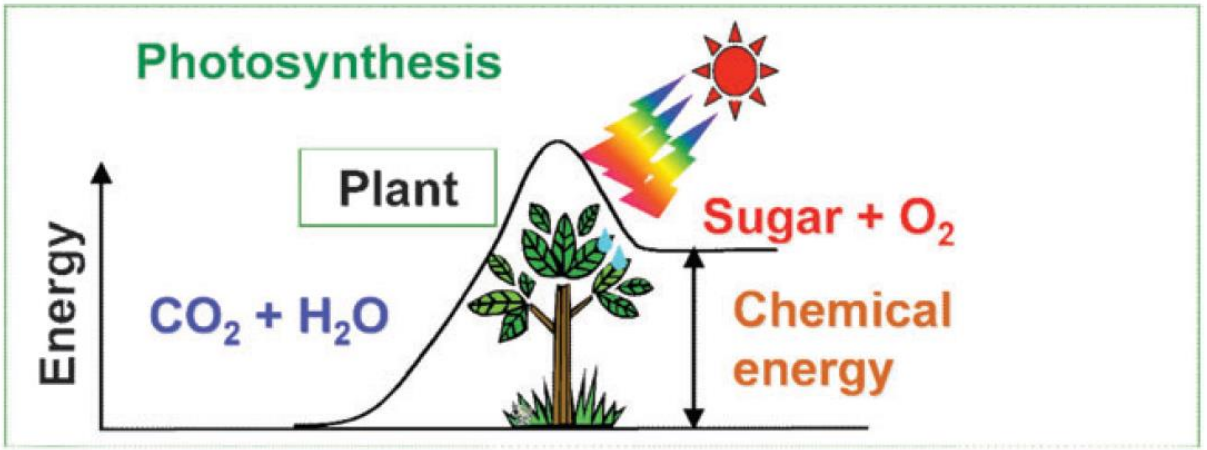


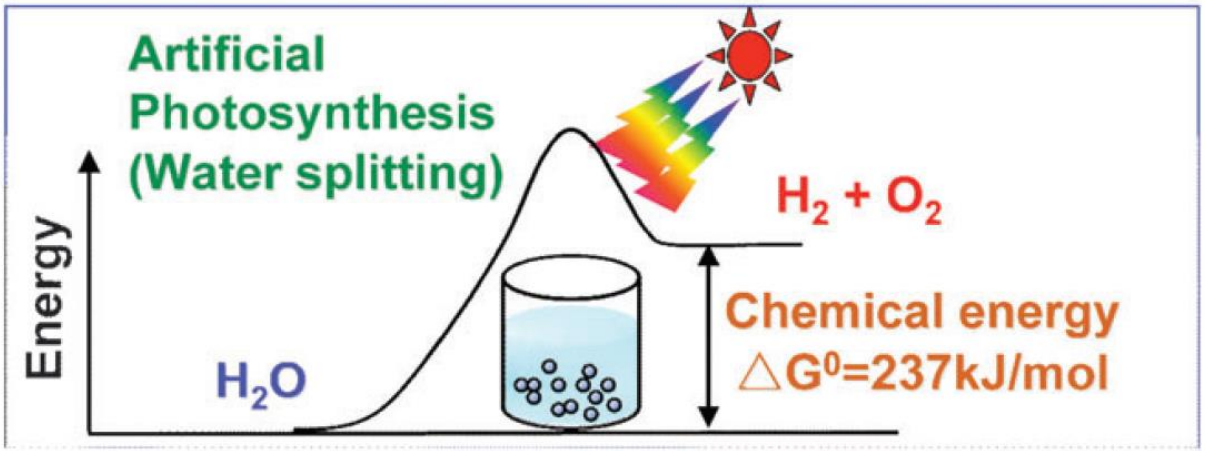
Solar Energy Conversion Technologies



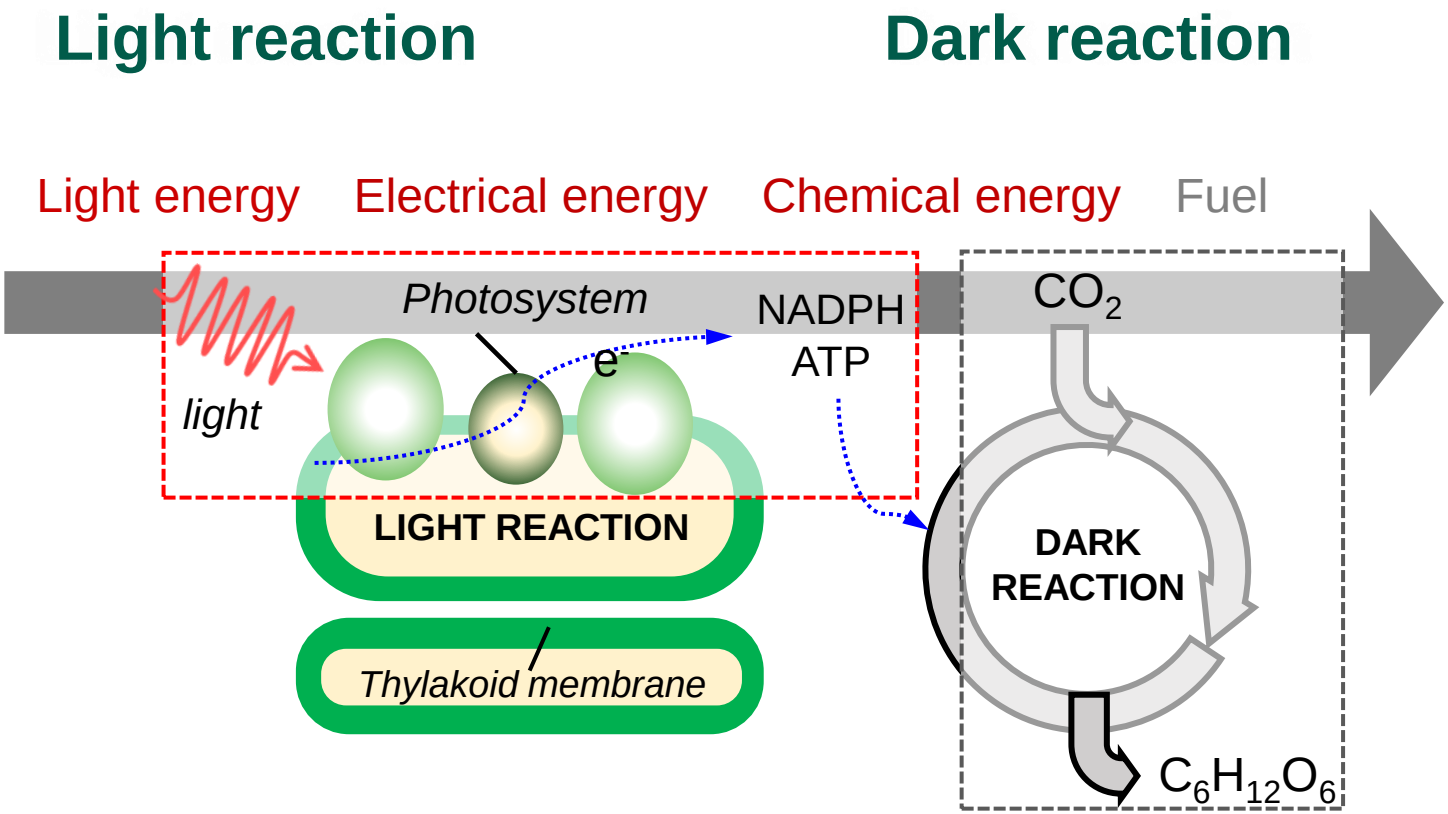
Photocatalytic water splitting



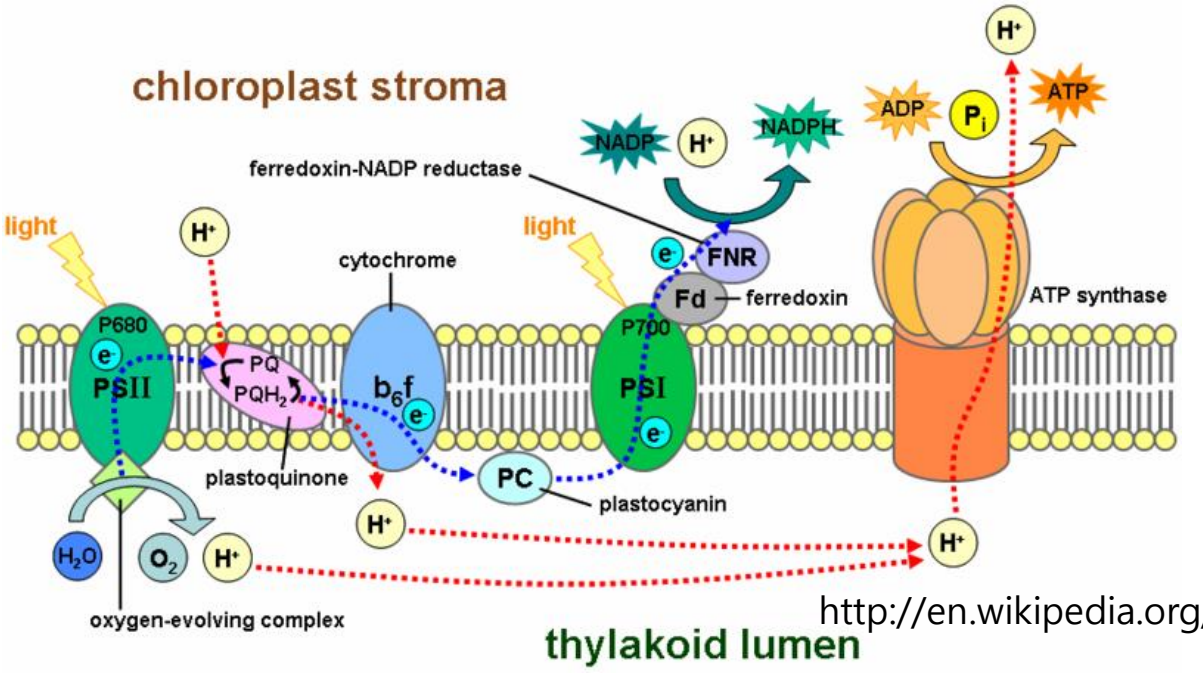




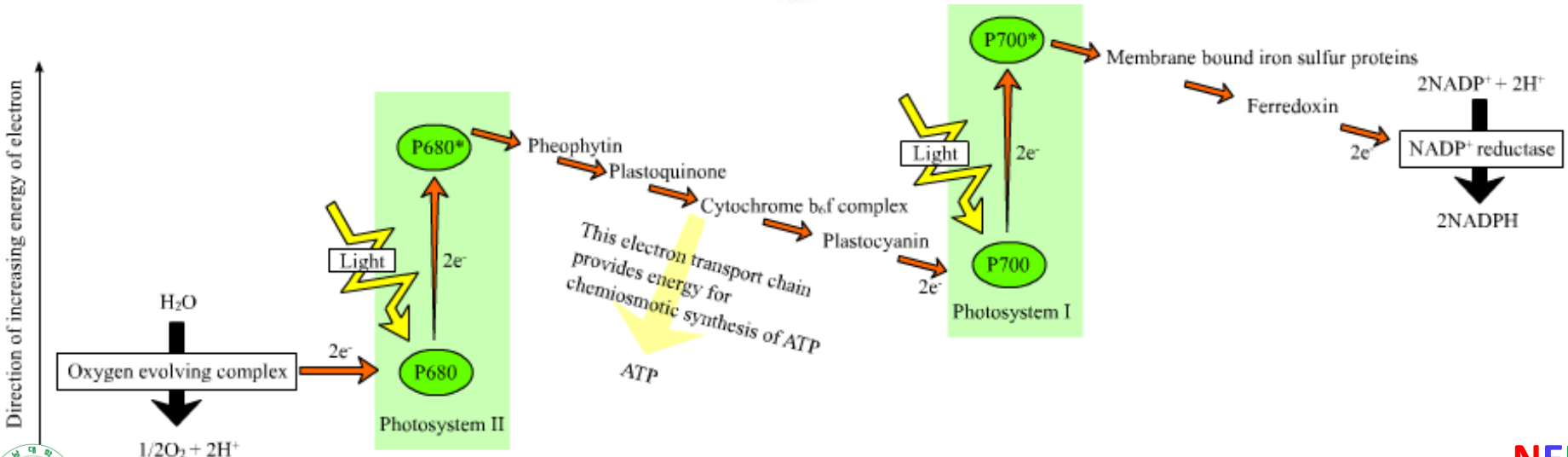
Photosynthesis



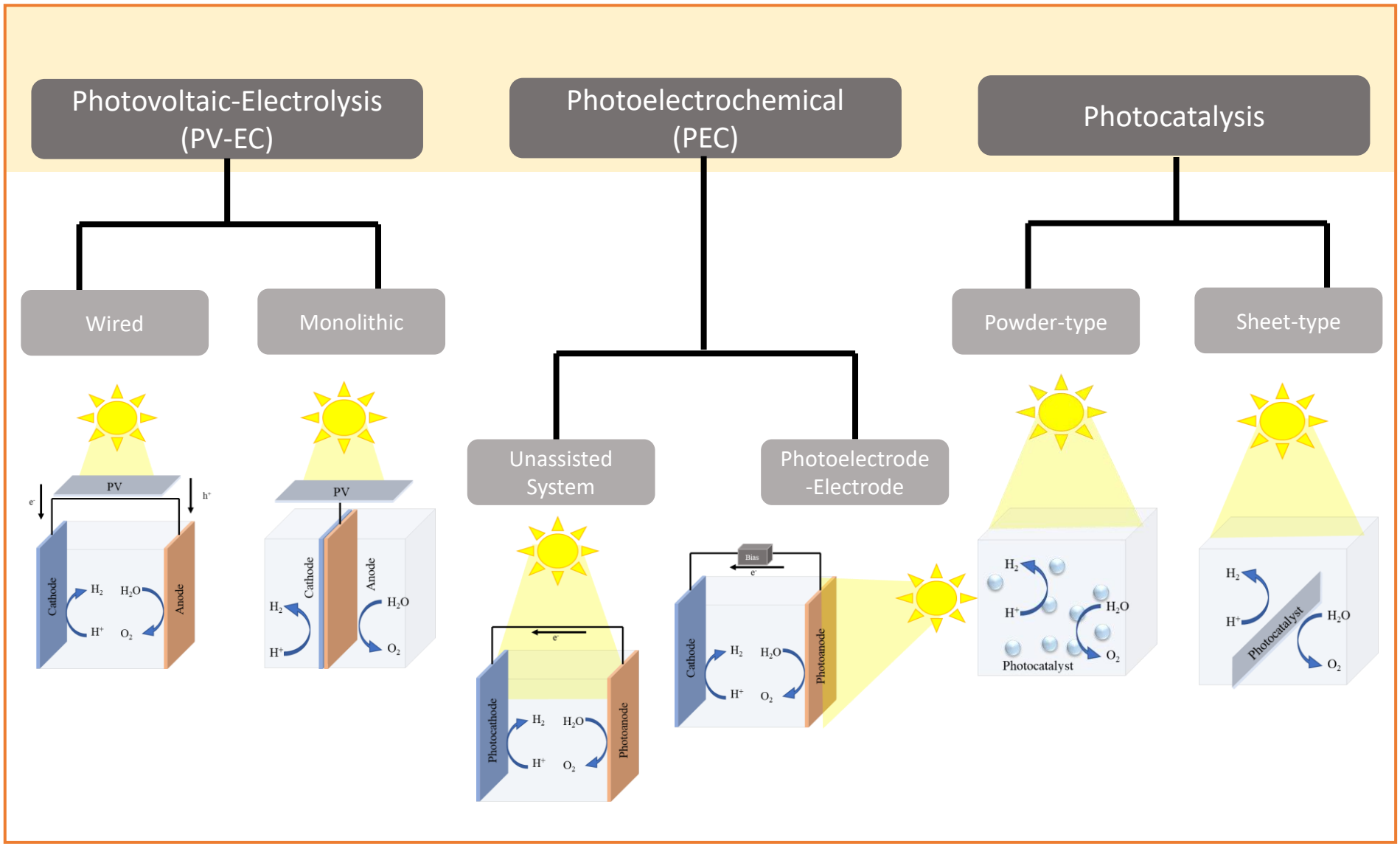
Z-scheme of photosynthesis



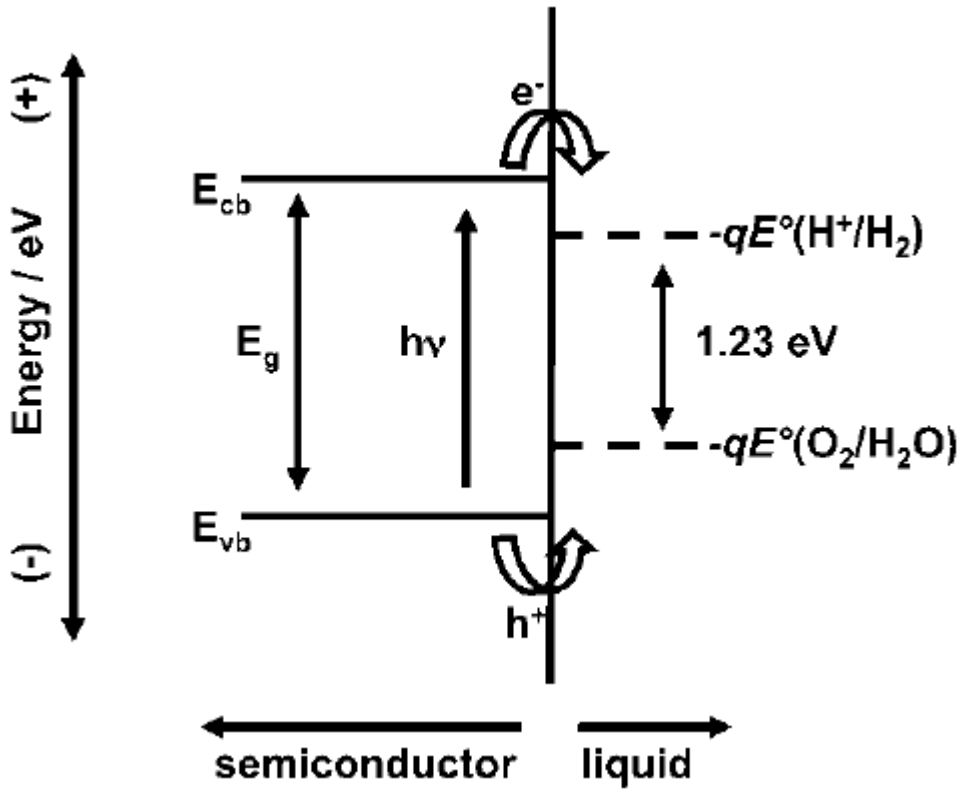
http://en.wikipedia.org/wiki/Photosynthesis



Solar Water Splitting



Semiconductor/Liquid Junction



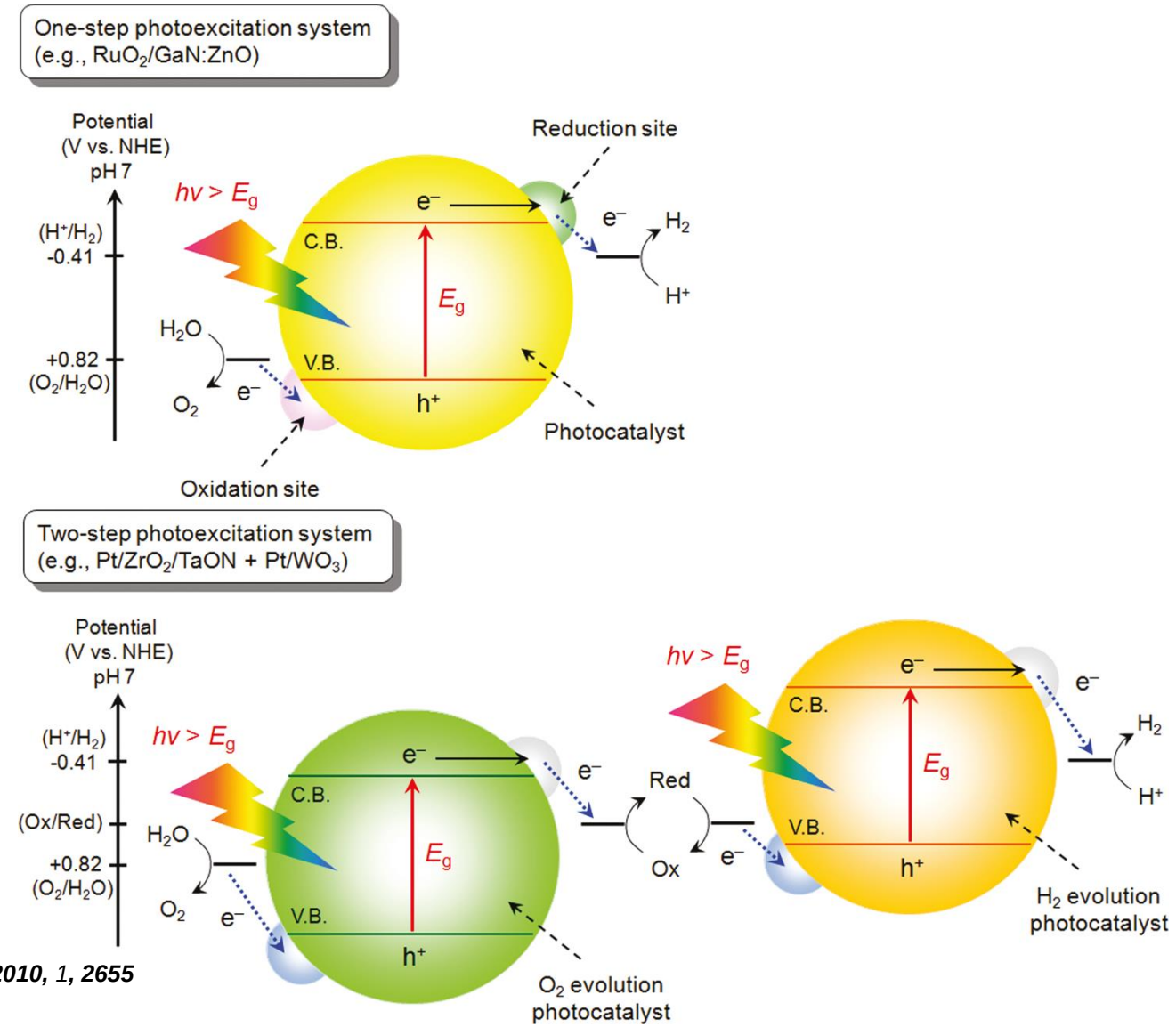
$H_2O + 2h^+ \rightarrow ½\ O_2 + 2H^+$ (Oxygen Evolution Reaction)

$2H^+ + 2e^- \rightarrow H_2$ (Hydrogen Evolution Reaction)

$H_2O \rightarrow H_2 + ½\ O_2$

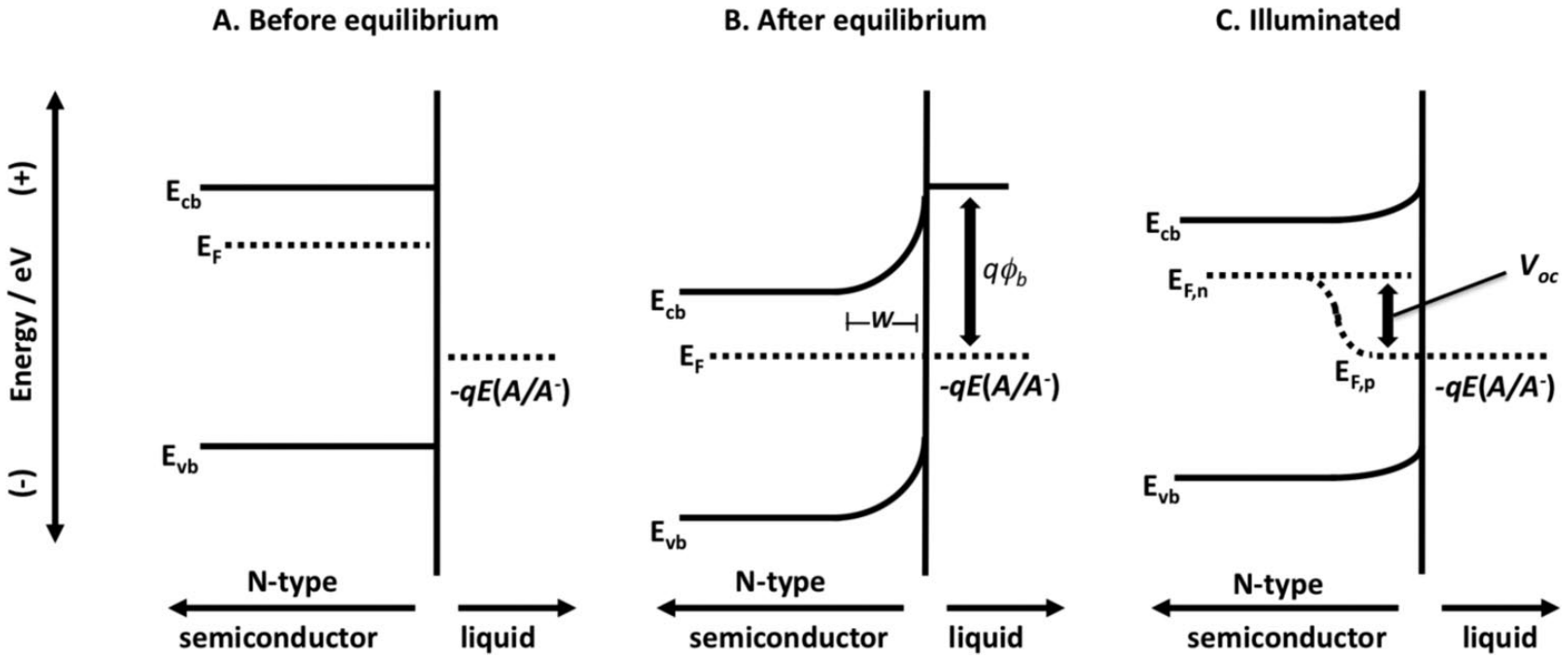
$\Delta G_0 = 237$ kJ/mol ($E_0 = -1.23$V)

Mimicry of the Z-scheme process



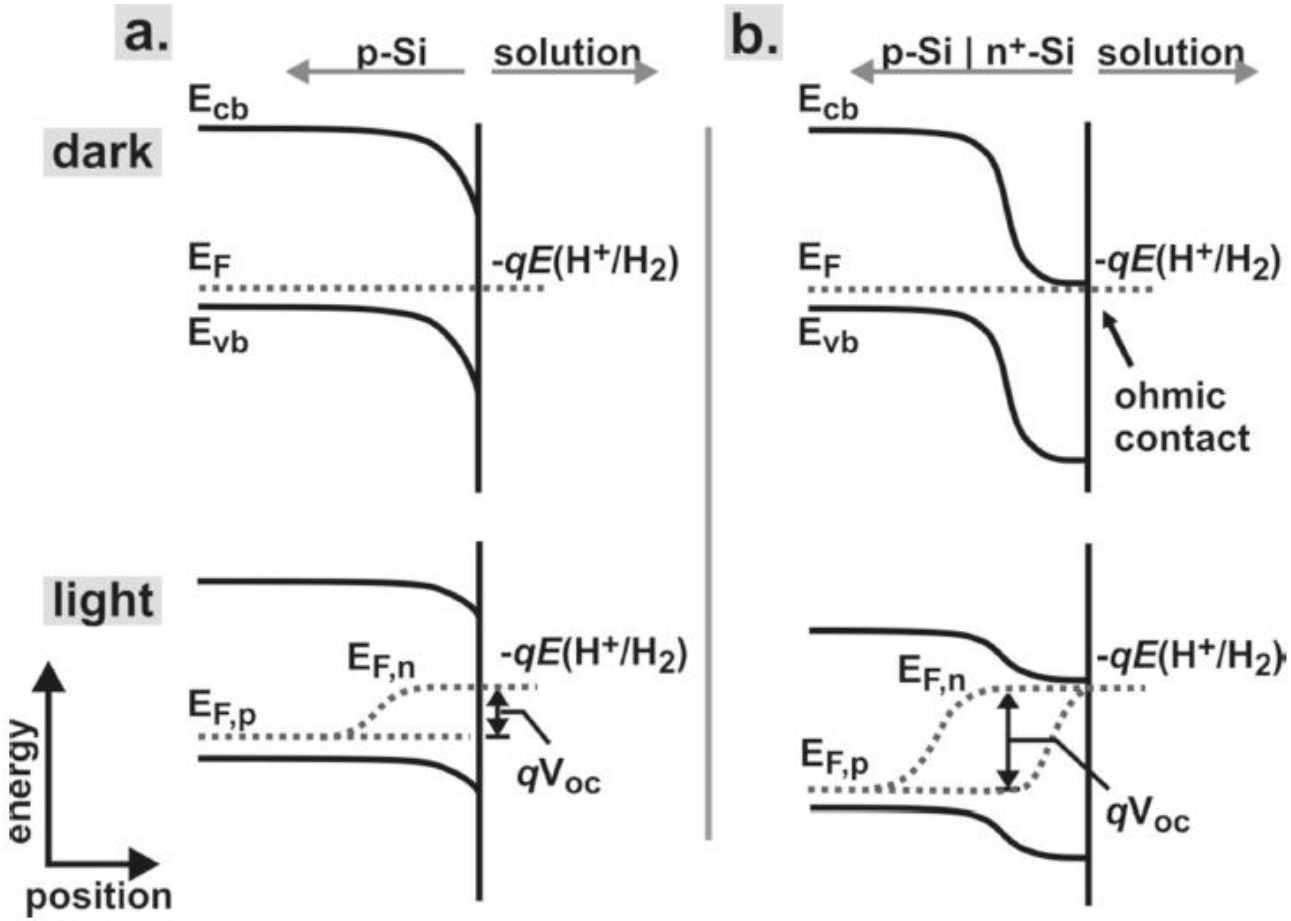
J. Phys. Chem. Lett. 2010, 1, 2655

Band energetics of a semiconductor/liquid contact

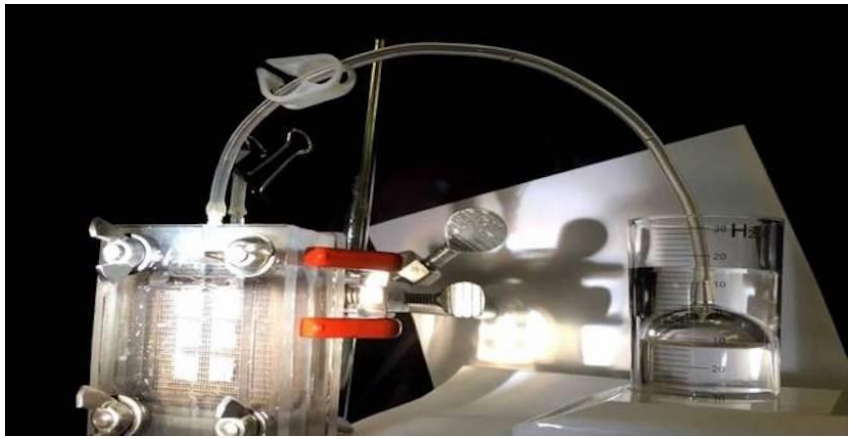


The positive charge is spread out over the depletion width, *W*, in the semiconductor, whereas the negative charge is spread over a much narrower region (the Helmholtz layer) in solution, close to the electrode.

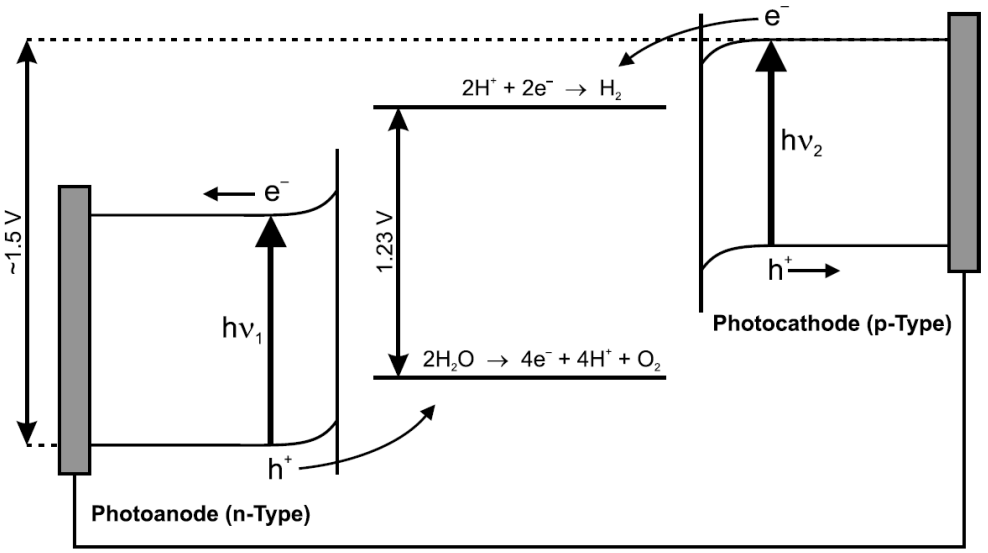
p-n$^+$ junction


a.
p-Si
solution
dark
E_{cb}
E_F
$-qE(H^+/H_2)$
E_{vb}
light
$E_{F,n}$
$E_{F,p}$
$-qE(H^+/H_2)$
qV_{oc}
energy
position
b.
p-Si | n+-Si
solution
E_{cb}
E_F
$-qE(H^+/H_2)$
E_{vb}
ohmic
contact
$E_{F,n}$
$E_{F,p}$
$-qE(H^+/H_2)$
qV_{oc}

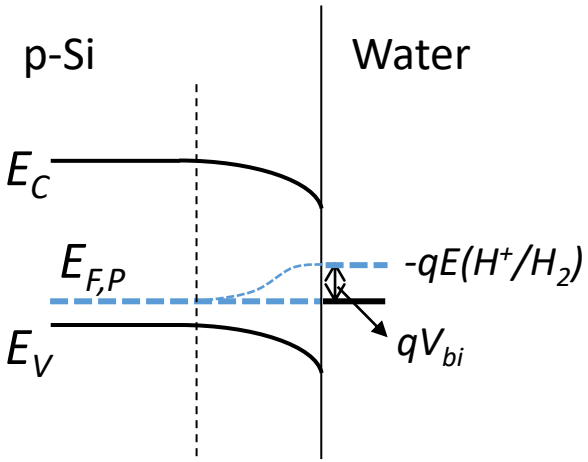
PEC with pn junction



HyperSolar Inc.



Si without pn junction



Si with pn junction