Universidad Tecnológica Nacional
Facultad Regional Paraná

Ingles II
Electronics Engineering Department

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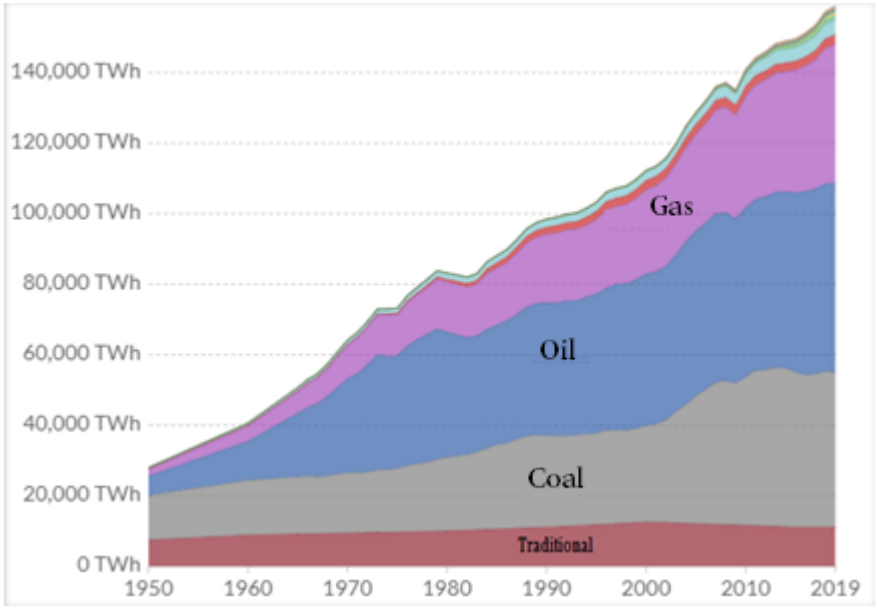
2020

Applications of Organic Cells in Buildings: Integrated Photovoltaic Systems

Global energy consumption from 1950 to 2019

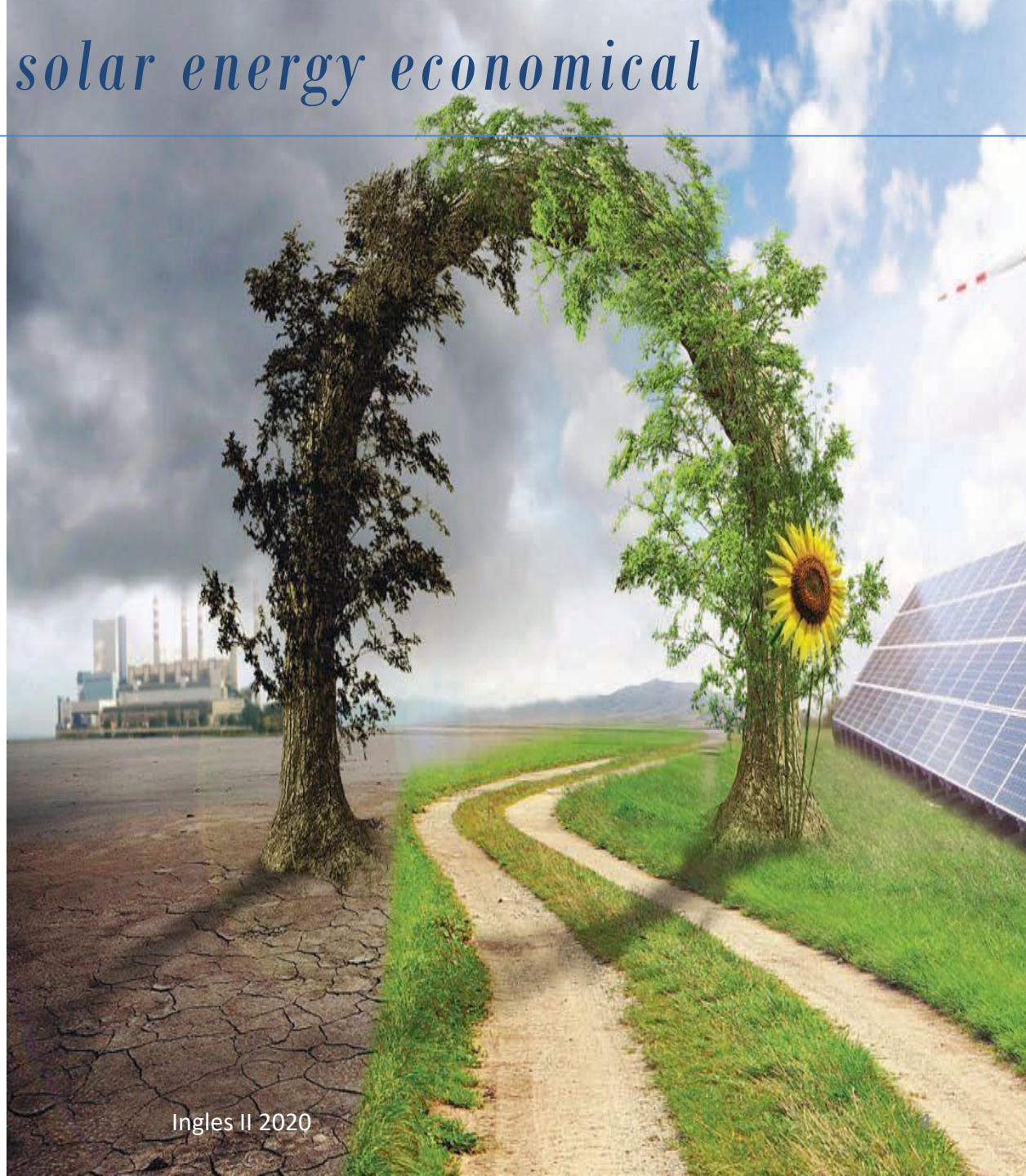
www.ourworldindata.com



- The increase has been more than 250%
- Current energy systems are still dominated by fossil fuels

Making solar energy economical

- Moving towards renewable energies
- Electrical energy to all
- Ecological problems
- Sustainable development
- A key factor for human wellbeing
- Cost of sillicon cells
- Potential of organic cells



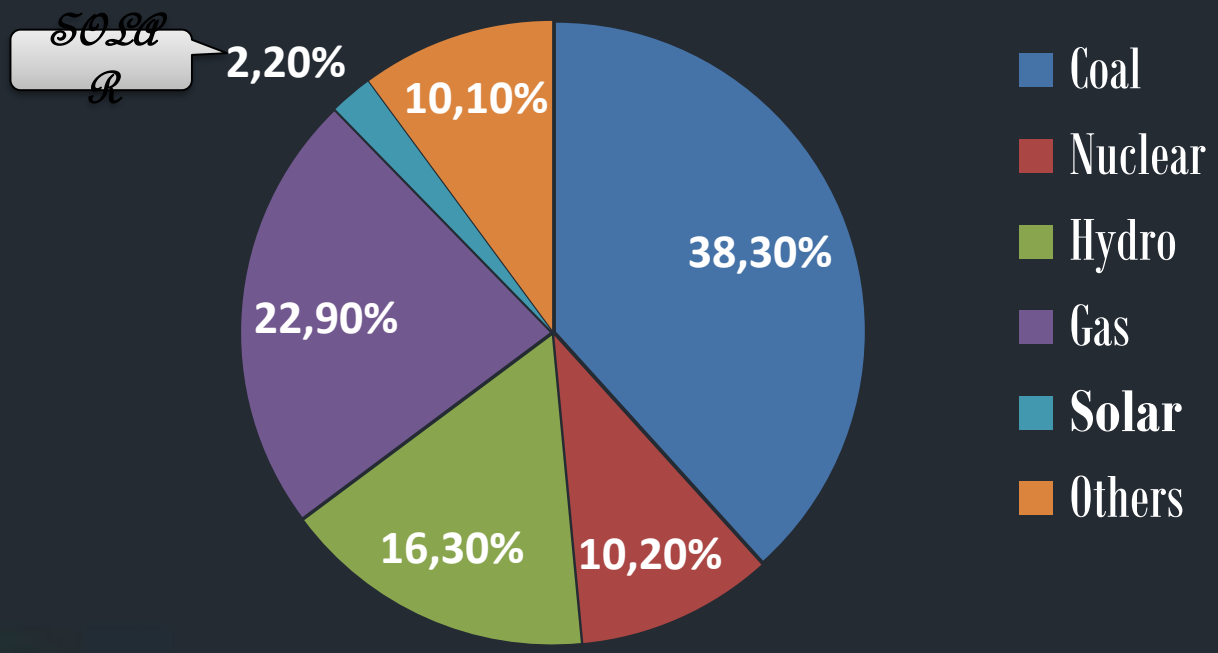
Subjects:

- Global solar energy production
- Organic cells: basic features
- Their potential to make solar energy ecnomical
- Applications on windows systems

Paper map

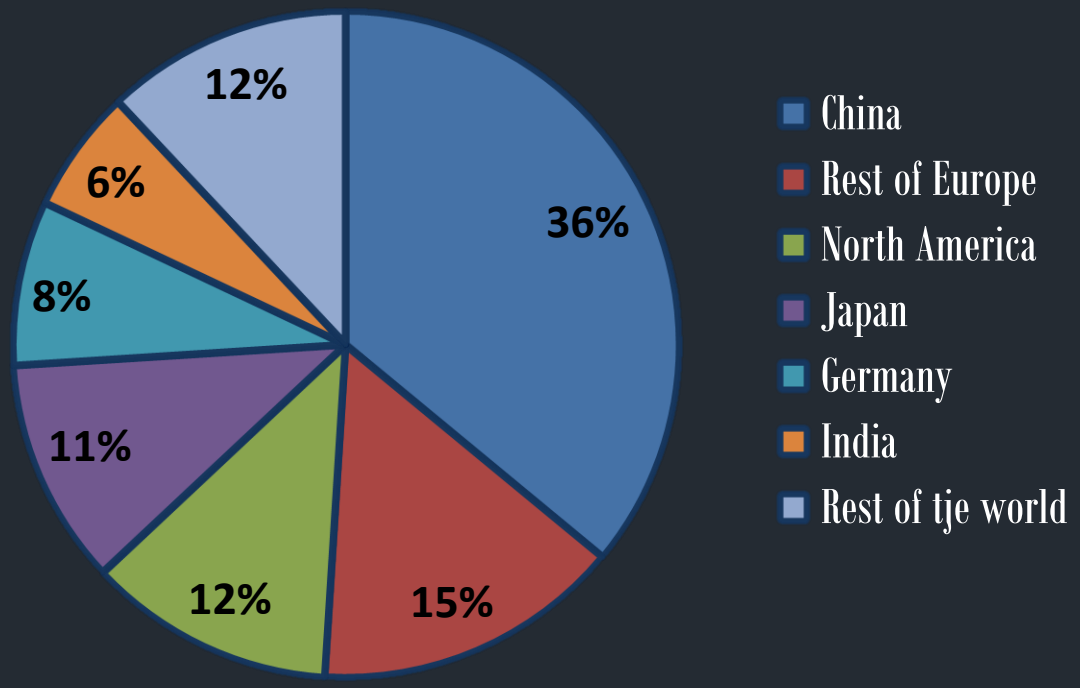
- 1- Solar production worldwide
- 2- Organic cells: working principles
- 3- Application in buildings
- *3.1- Modeling and simulation*
- *3.2- Efficiency and Transparency*
- 4- Application: Changeable solar cell windows

Global electricity production by source



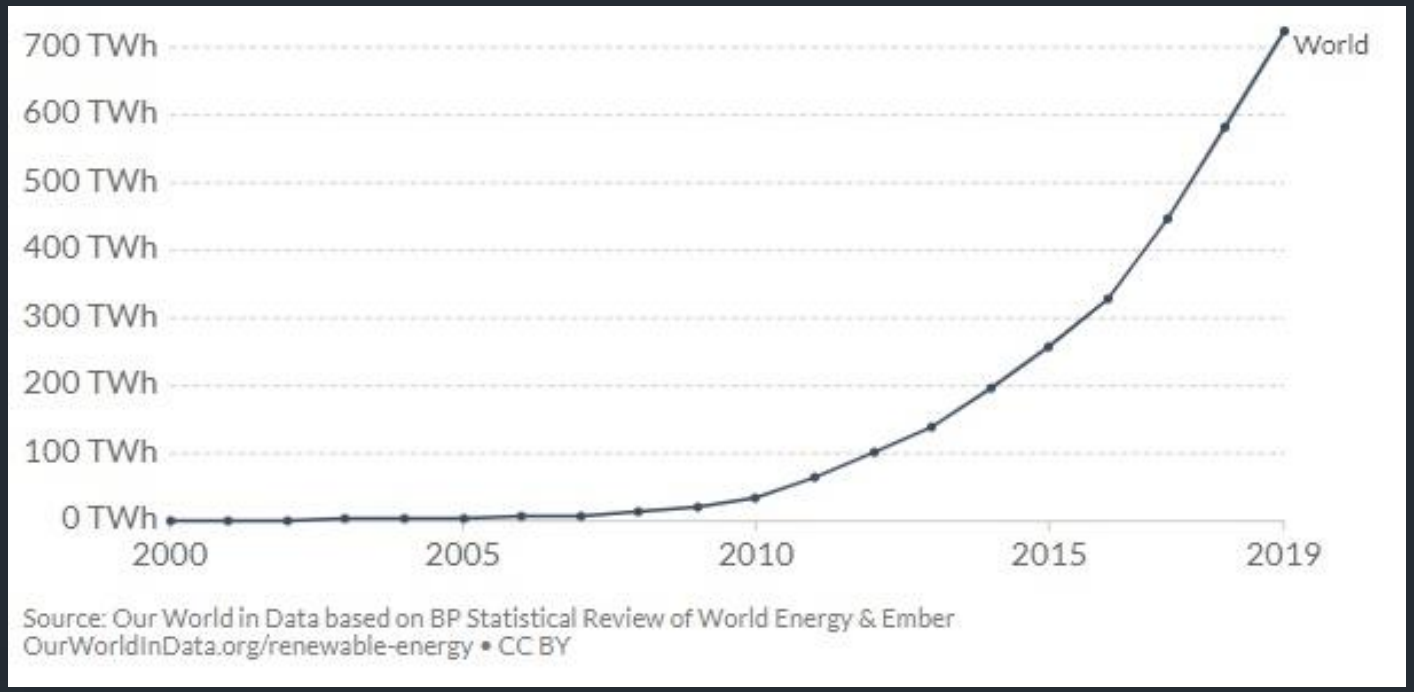
- Only 2.2 % of the global production is solar
- Coal and gas are the most used resources → greenhouse effect
- Many countries are abandoning nuclear energy

Solar energy production by country



- China is leading the world with 36%
- Europe contribute with 15%
- North America with 12%

Solar energy production growth



- The worldwide growth has being between 20% and 30% depending on the year
- The increase in 2019 was 22%.
  - Despite this improvements solar energy is still expensive

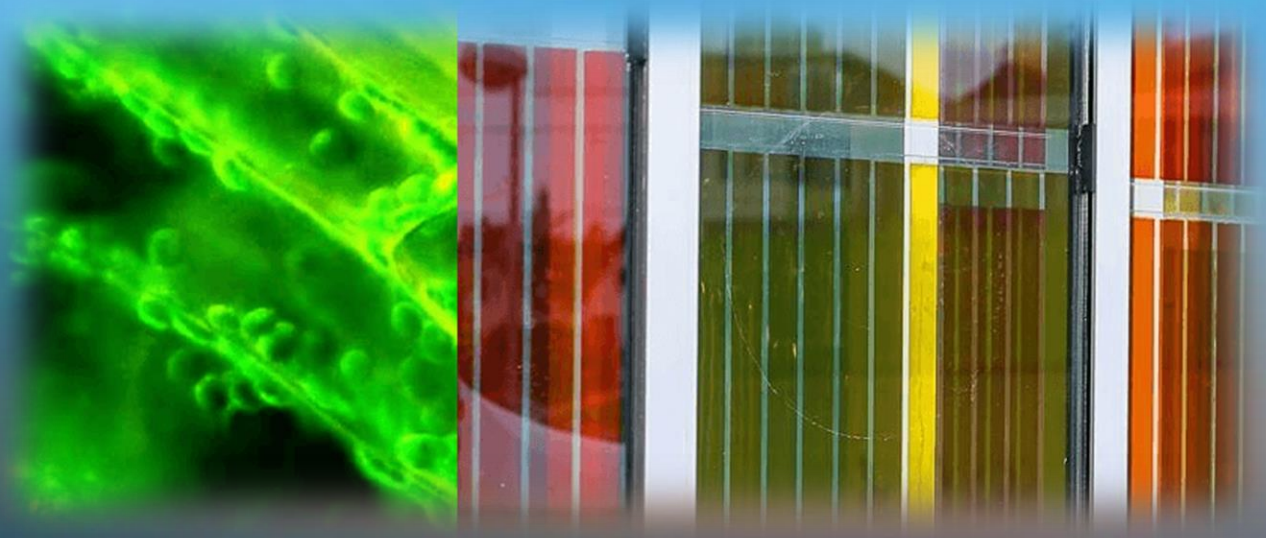
The problem of solar energy

- More than 90% of PV generation is due to sillicon cells
- They are efficient and well know technology
- ... but have high cost and complex production

- This is the greatest limitation to overcome

Part III

Organic cells



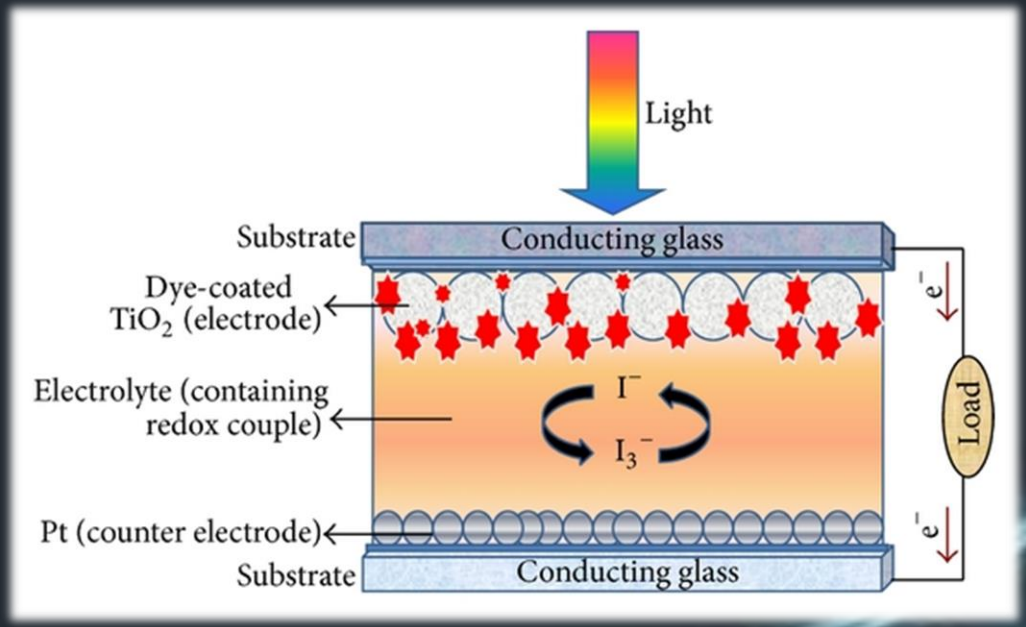
- It is a *photo-electrochemical* system
- It is based on a semiconductor, a photo-sensitized layer and an electrolyte

Why are they organic?

- They use organic molecules and polymers as the light-absorbing material

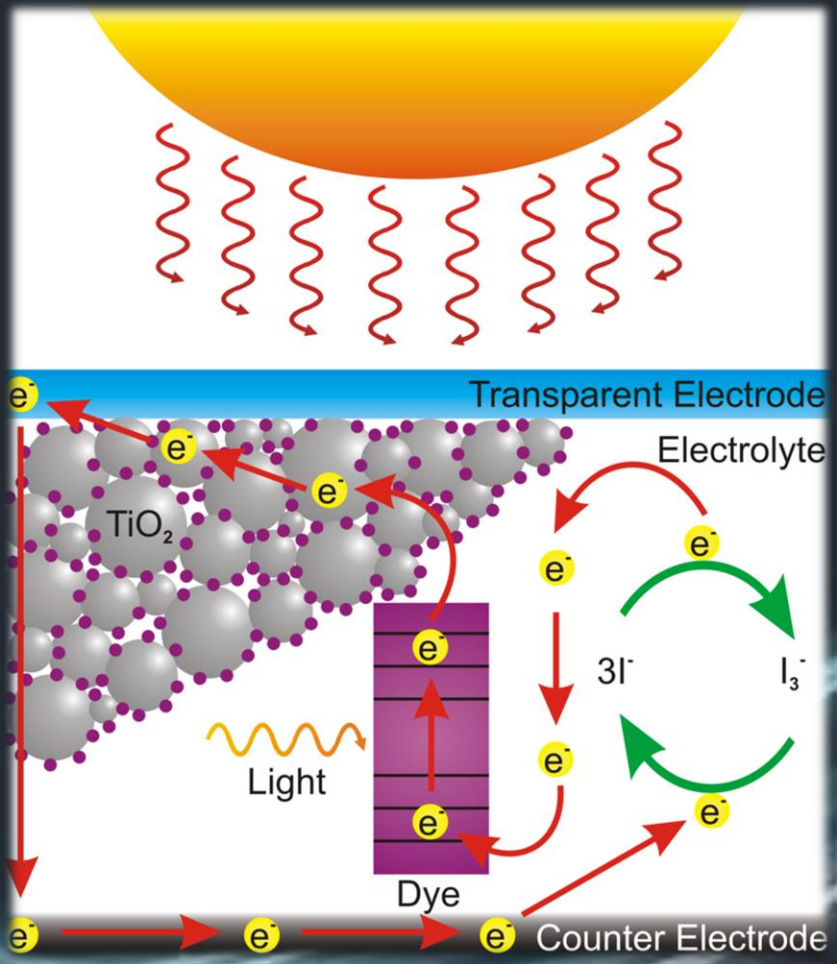
Organic Solar Cells Structure

- A mechanical support coated with transparent conductive glass .
- A semiconductor film, usually Titanium Dioxide (TiO2).
- An organic sensitizer absorbed onto the absorbed onto the surface of the of the semiconductor.
- An electrolyte containing a redox mediator.
- A counter electrode or cathode



Working Principle

- The dye sensitized TiO2 acts like an electron donor absorbing a photon.
- The excited dye sensitizer injects the electron into the conduction band of the semiconductor.
- The injected electron flows through the conducting glass
- Then it flows through the external load to the cathode counter electrode
- The electrolyte regenerates the sensitizer, completing the electro-chemical circuit.



ADVANTAGES OF ORGANIC CELLS

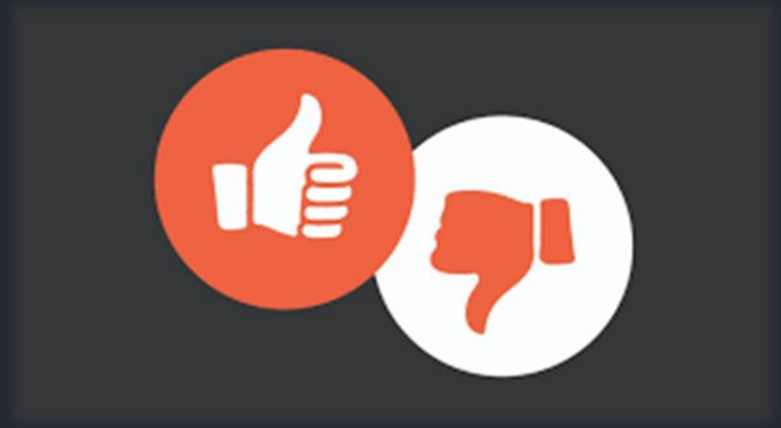
- They are flexible
- They are printable
- They have light weight
- They are low cost
- They can be fashionably designed
- They can be fabricated by roll-to-roll production
- They can be attached to the roofs, windows, and walls of houses and buildings.

Disadvantages

- The liquid electrolyte can generate stability problems in extreme weather

  ⟶ Freeze

  ⟶ Expand



- Replacing the liquid electrolyte with a solid is a major field of research

PART IV

Efficiency and Transparency

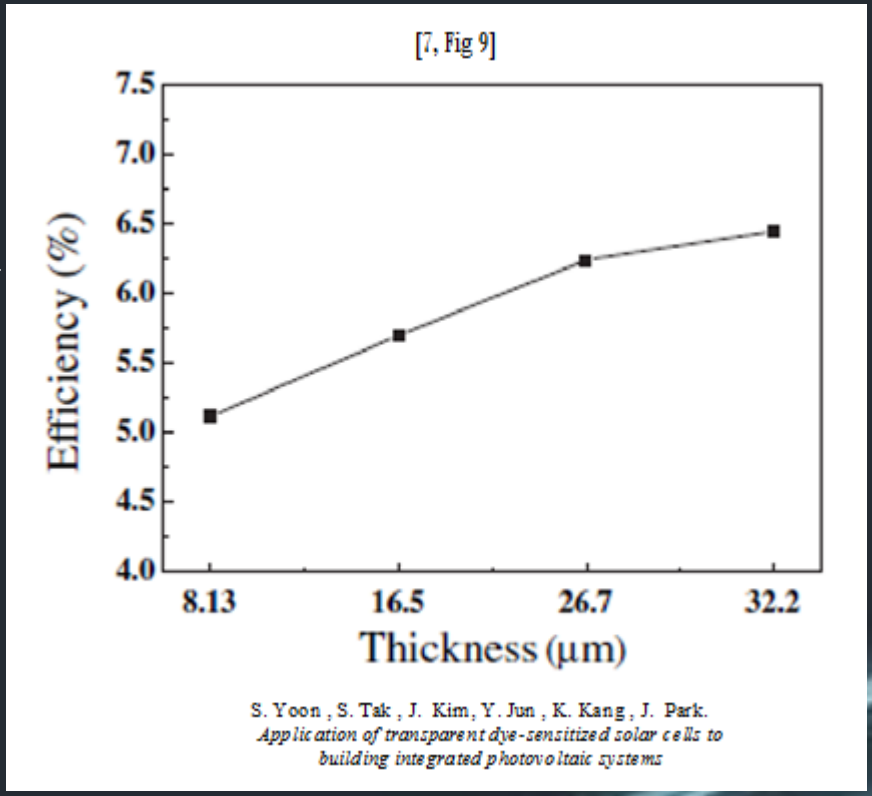
- The important parameters
- How to calculate them

Efficiency vs Transparency

- The electricity generated is proportional to the interaction of the organic material with light

- The efficiency grows with the organic layer

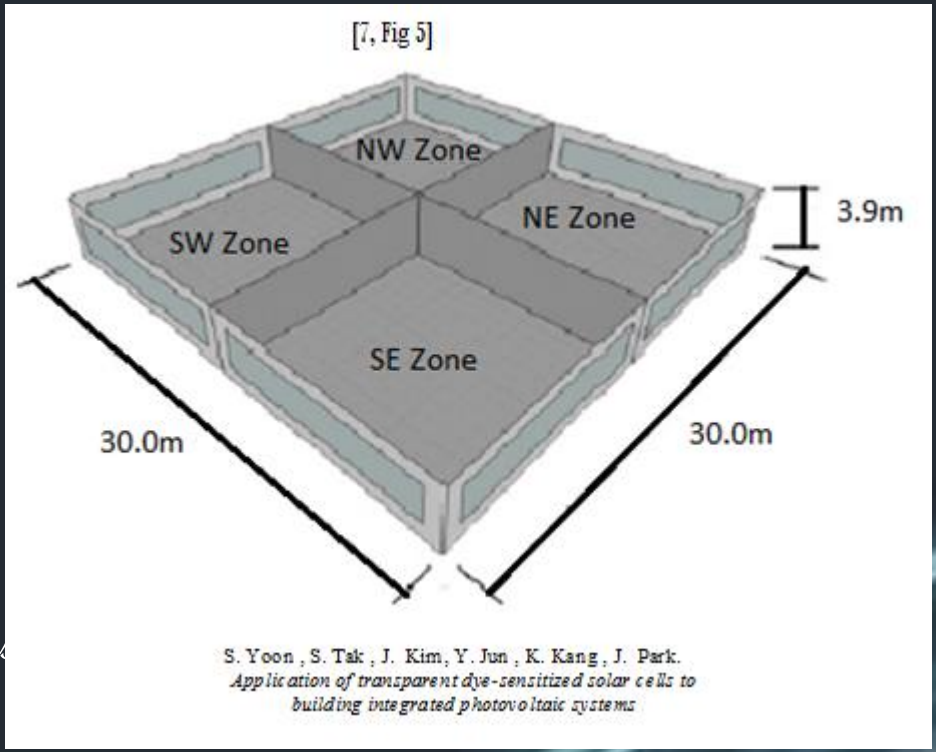
- As the organic layer grows, the transparency of the cell decreases, blocking the passage of light



- The optimal balance must be found between efficiency and transparency.

Simulation

- With these experimental data we can simulate to evaluate the efficiency
- Room with 30m x 30m floor and 3.9m high walls.
- The walls facing Northwest, Northeast, Southwest, and Southeast (w-w ratio 50%)
- 2 Situations: for regular windows and windows with organic solar cells.



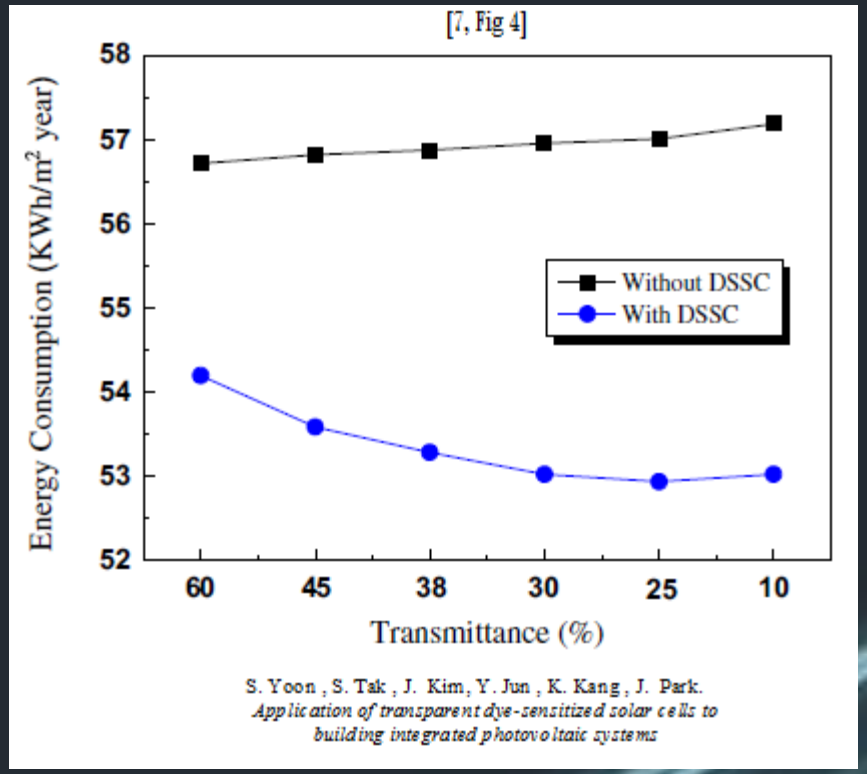
Consumption vs Transparency

- Consumption in kW/m^2 per year

→ Black line: normal window

Blue line: Organic cell window

- Lowest energy consumption is achieved when the transmittance is 25%. (11.6 % saving)



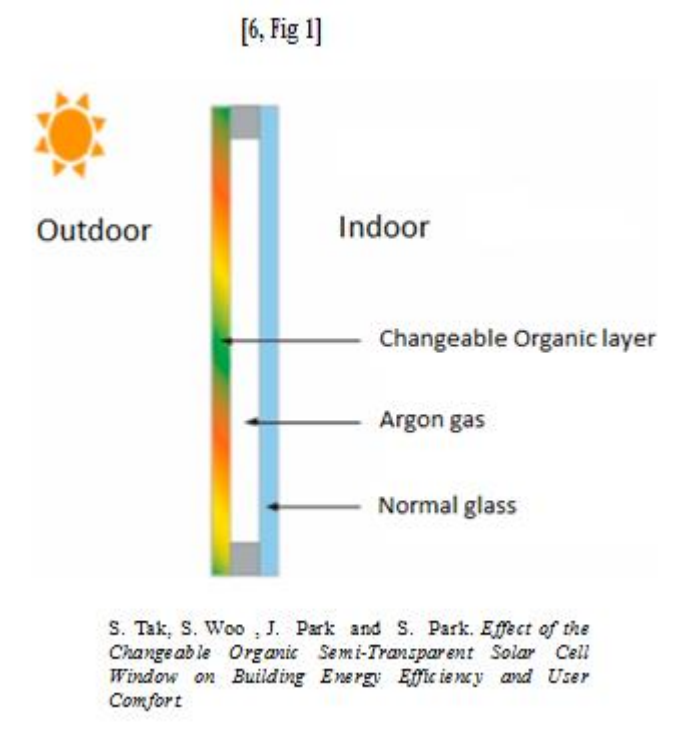
- The simulation allows to eliminate non optimal parameters values before fabrication

PART V

CHANGEABLE
SEMI TRANSPARENT
SOLAR CELL
WINDOWS

CHANGEABLE ORGANIC SOLAR CELL WINDOW

- Two layers separated with an argon gas gap of 3mm
- The argon gas provides thermal and UV insulation
- The solar cell is the outer layer.
- The indoor layer is normal glass
- It changes its transparency automatically with weather conditions



Modeling

- The system can go through 5 states modifying its transparency and Solar Heat Gain Coefficient

- *Configurated with 4 parameters:*

- Transmittance: *0.536 – 0.603*
  SHGC: *0.479 – 0.493*
  Open–voltaje: *0.58 V*
  Short circuit current: *9.7 mA/cm2*

- Transmittance and SHGC models interaction with light

- Open-voltaje and short circuit current models electrical properties

Results

- The electricity production was between 2.3 and 5.6 kW/m^2
- Energy savings were between 7.6 and 11.4 kW/m^2
- Reduction in total energy consumption: between 11.5 and 15.0 kW/m^2
- Orientation is important, being north direction the only drawback

Reference calculation

- Energy consumption by square meter in France for a normal comercial building. Reference 1 $\sim 175\ kW/m^2$

- If we take the previous result of $15\ kW/m^2$ for reduction in consumption

✓ This mean a reduction of 8,6% in energy consumption by year

Data by Malidin et. al. [13]

[12, Fig 7]

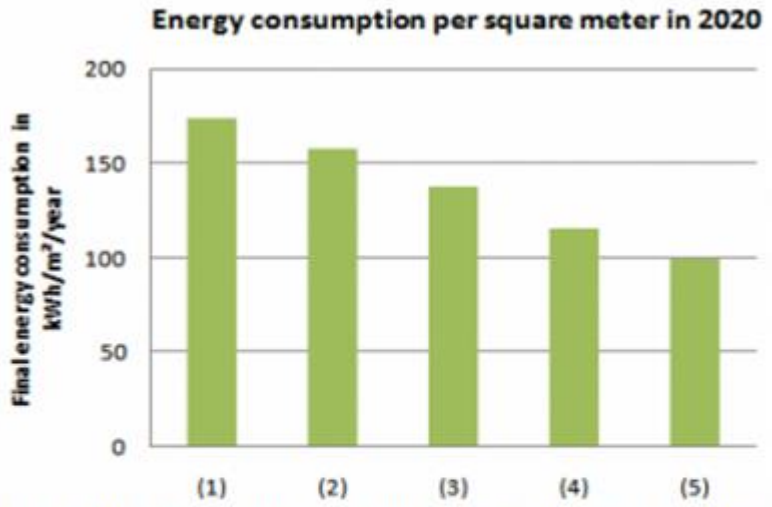
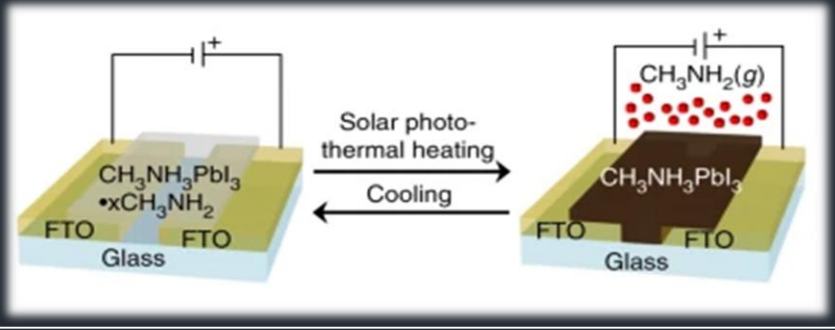
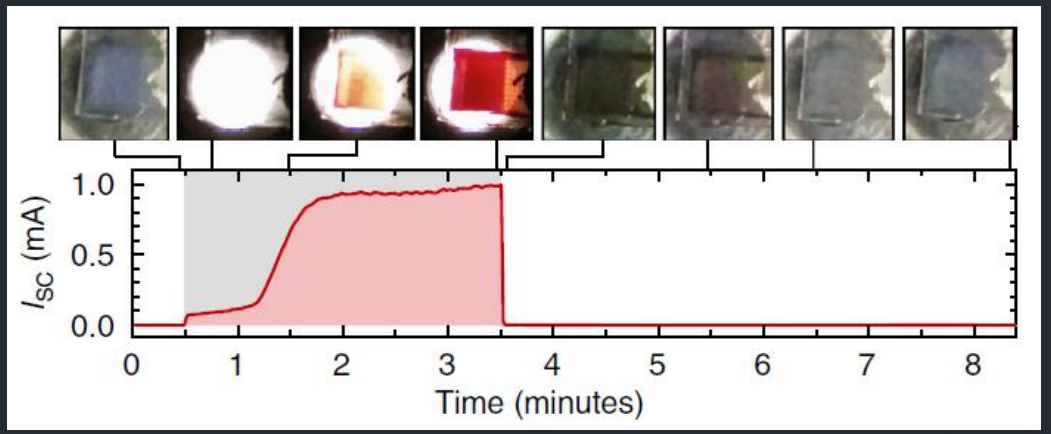


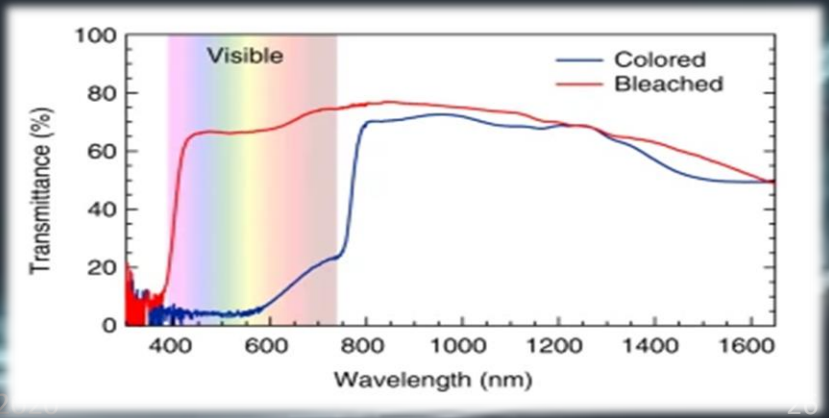
Fig. 7. Average energy use per square meter and per year in 2020, for the French commercial sector, in various cases:
(1) "Reference" without smart building
(2) "Reference" with smart building
(3) "Eco-friendly" with smart building
(4) "Eco-friendly" without smart building, total consumption is constrained
(5) "Eco-friendly" with smart building, total consumption is constrained

SWITCHABLE PHOTOVOLTAIC WINDOW by Wheeler et. al. [11]

- Based on perovskite which is a very good PV absorber
- It works by changing the chemical composition of one of its layers by solar heating
- The heat dissociate an organic complex (CH_3NH_2) from the perovskite light absorbing layer.
- Highly absorbing in the opaque state (blue) and have high transmittance in the transparent state (red)







Results

- 3% to 68% modulation range
- Power efficiency conversion of 11.3%
- 20+ possible states
- Switching times of less than 3 min.

- Simulated cases: 11.6% and 8.6%
- Experimental case: 11.3%

~ 10%

Conclusion

- Organic cells and their application to window systems have been presented
- A simulation method to analyze the performance and optimal parameters (25% transparency - 11.6% savings by year) has been proposed
- A window with organic cells (COSW) and a Switchable PV Window based on perovskite has been studied
- The COWS window is capable of saving around 15 kW / m2 of energy per year (8,6%)
- Switchable PV Window reached 11.3% of power conversion efficiency

Conclusion

Organic cell window technology has great potential

- to reduce energy consumption
- to overcome the limitations of silicon cells

✓ lowering cost and complexity

✓ improving structural versatility and design

✓ improving efficiency – cost ratio

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THANKS!

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