PHOTOVOLTAIC'S TECHNOLOGY OVERVIEW

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29 - 30 May 2014

Aphrodite Hills Hotel, Paphos

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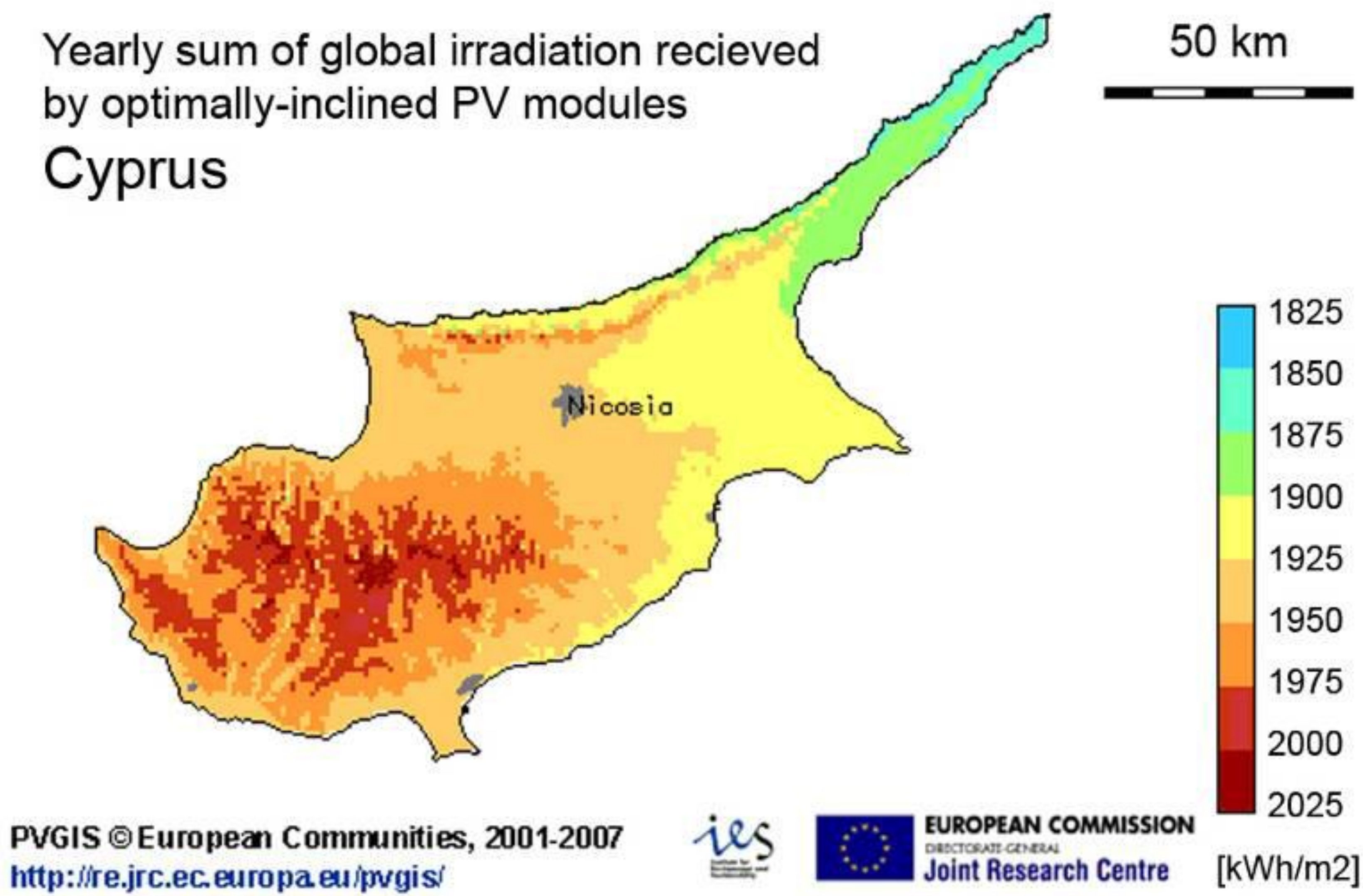
The highest Solar Irradiation In Europe



Available Technologies

TECHNOLOGIES

- **Crystalline Silicon**
  - **Mono-Crystalline**
  - **Poly-Crystalline**
- **Thin Film**
  - **Amorphous-Si (a-Si)**
  - **Cadmium Telluride**
  - **CIGS (Copper Indium Gallium Selenide)**
- **Compound Semiconductor**
  - **Light absorbing Dyes**
  - **Organic**
  - **Other**
- **Nanotechnology**
  - **Carbon nanotubes**
  - **Quantum dots**
  - **Hot carrier solar cell**
- **CPV**

Available Technologies

Mono-crystalline silicon

Poly-crystalline silicon

Flexible amorphous thin film

CIGS thin film

Available Technologies

<u>**Silicon Crystalline**</u>

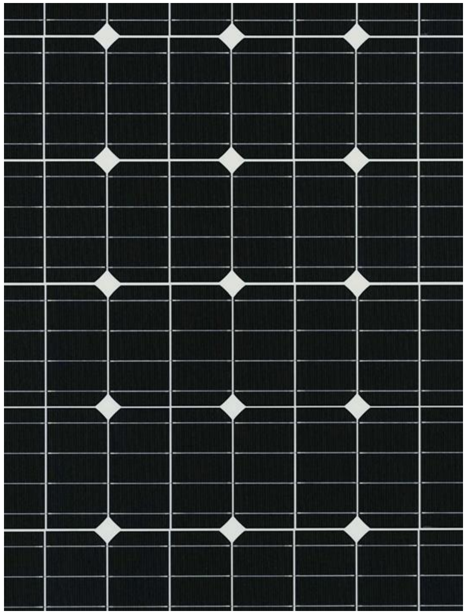
- The first generation of PV technologies is made of crystalline structure which uses silicon (Si) to produce the solar cells that are combined to make PV modules.
- This technology is constantly being developed to improve its capability and efficiency.



Available Technologies

Mono-Crystalline,

- This type of cell is the most commonly used, and will continue to be the leader until a more efficient and cost effective PV technology is developed. It essentially uses crystalline Si p–n junctions
- Efficiency of mono-crystalline silicon solar cell has reached around 23% (laboratory scale)



Available Technologies

Poly-Crystalline

- The efforts of the photovoltaic industry to reduce costs and increase production have led to the development of new crystallization techniques. Poly-crystalline was the outcome of these efforts. Such technology is becoming more attractive because manufacturing cost is lower even though these cells are slightly less efficient (15%)

Available Technologies
Thin Film

- Unlike crystalline forms of solar cells, where pieces of semiconductors are sandwiched between glass panels to create the modules, **thin film panels** are created by depositing thin layers of certain materials on glass or stainless steel (SS) substrates, using sputtering tools.
- The resulting advantage is a lowering in manufacturing cost.
- Four kinds of thin film cells have emerged as commercially important: the **amorphous silicon** cell (multiple-junction structure), the **thin poly-crystalline** silicon, the **copper indium** diselenide/cadmium sulphide hetero-junction cell, and the **cadmium telluride** / cadmium sulphide hetero-junction cell.
- Efficiencies of thin film solar modules are lower than crystalline.

Available Technologies

Amorphous

- Amorphous silicon (a-Si) is one of the earliest thin film technologies developed. This technology diverges from crystalline silicon in the fact that silicon atoms are randomly located from each other.

Available Technologies

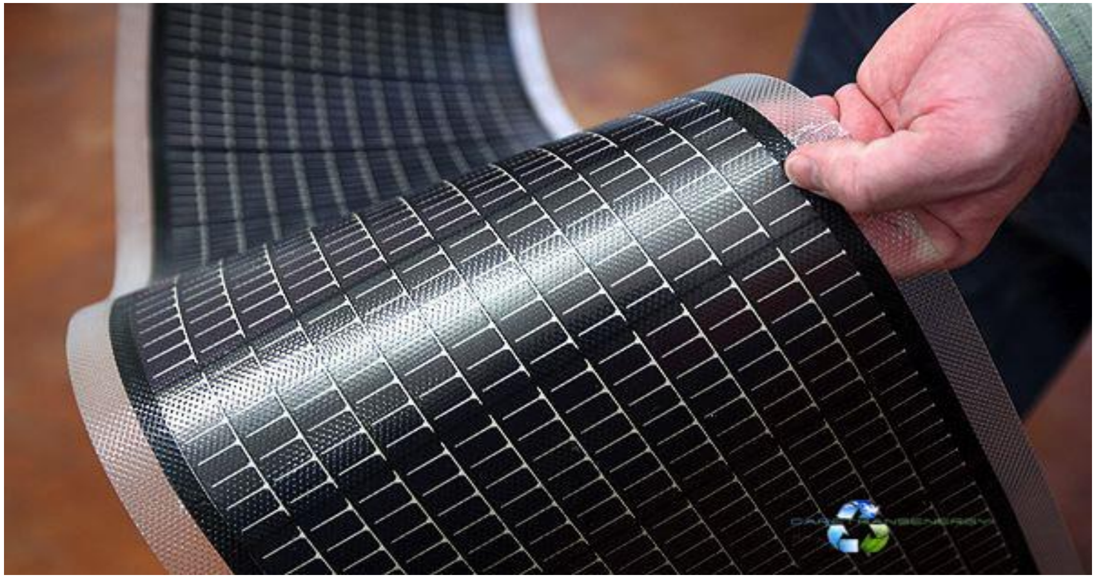
Amorphous-Si, double or triple junctions

- a-Si cells have lower efficiency than the mono- and poly-crystalline silicon counterparts.
- To improve the efficiency and solve the degradation problems, approaches such as developing multiple-junction a-Si devices have been attempted.

Available Technologies

Cadmium Telluride

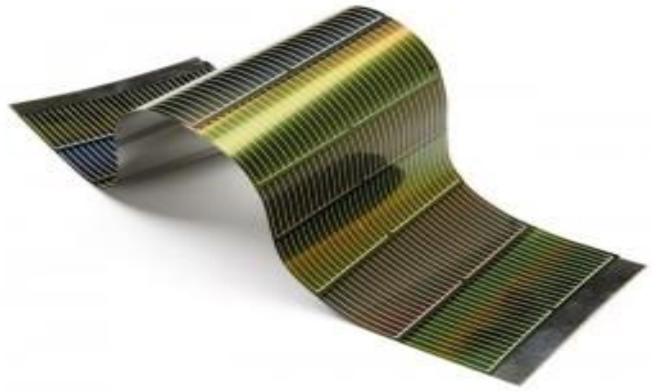
- Cadmium telluride (CdTe) has long been known to have the ideal band-gap (1.45 eV) with a high direct absorption coefficient for a solar absorber material and recognized as a promising photovoltaic material for thin-film solar cells.
- Small-area CdTe cells with efficiencies of greater than 15% and CdTe modules with efficiencies of greater than 9% have been demonstrated.



Available Technologies

Copper Indium Gallium Selenide (CIGS)

- CIGS are photovoltaic devices that contain semiconductor elements that are beneficial due to their high optical absorption coefficients and electrical characteristics.
- Better uniformity is achieved through the usage of selenide.
- CIGS (indium incorporated with gallium – increased band gap) are multi-layered thin-film composites. The best efficiency of a thin-film solar cell is 20% with CIGS and about 13% for large area modules The biggest challenge for CIGS modules has been the limited ability to scale up the process.



Available Technologies

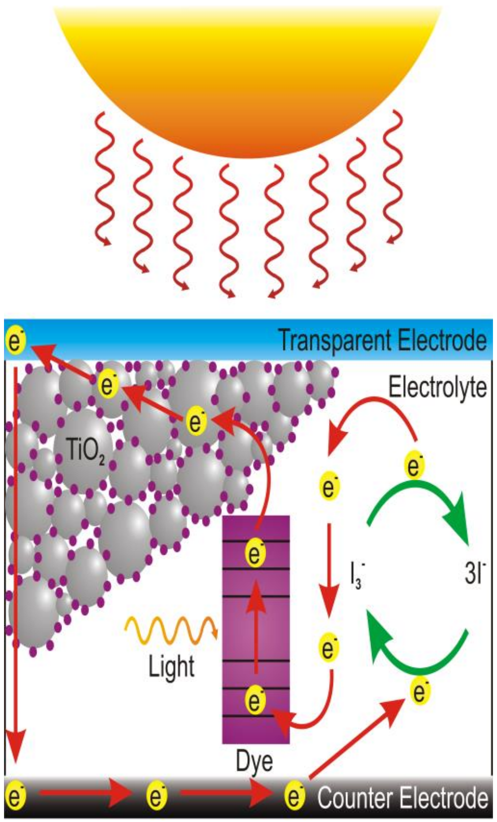
Compound Semiconductor

Light Absorbing Dyes

- Generally these types of cells consist of a semiconductor, such as silicon, and an electrolytic liquid, which is a conducting solution commonly formed by dissolving a salt in a solvent liquid, such as water.

- The source of the photo-induced charge carriers is a photosensitive dye that gives the solar cells their name: “dye-sensitized”.

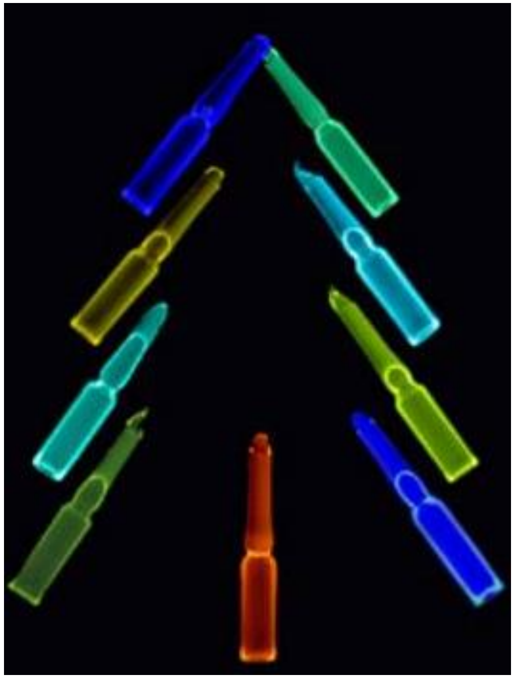
- While the highest efficiency dye-sensitized solar cell ever made is 11%, this technology contains volatile solvents in their electrolytes that can permeate across plastic (i.e. organic compounds) and also present problems for sealing the cells.



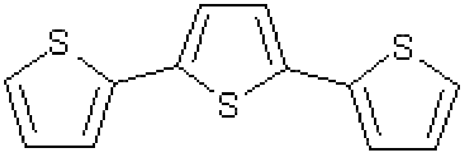
Available Technologies

Compound Semiconductor

Organic



- Organic solar cells and polymer solar cells are built from thin films (typically 100 nm) of organic semiconductors such as polymers and small-molecule compounds.
- 4–5% is the highest efficiency currently achieved using conductive polymers, however, the interest in this material lies with its mechanical flexibility and disposability.
- Since they are largely made from plastic opposed to traditional silicon, the manufacturing process is cost effective (lower-cost material, high throughput manufacturing) with limited technical challenges.



Images found at http://www.isof.cnr.it/ppage/capob/thiof.html

Available Technologies

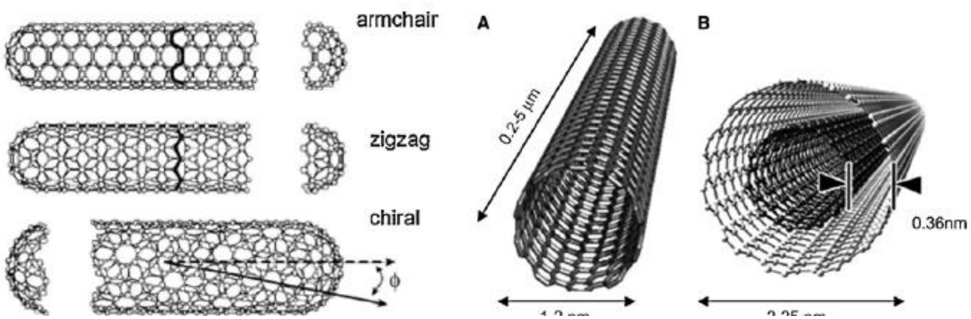
Nanotechnology

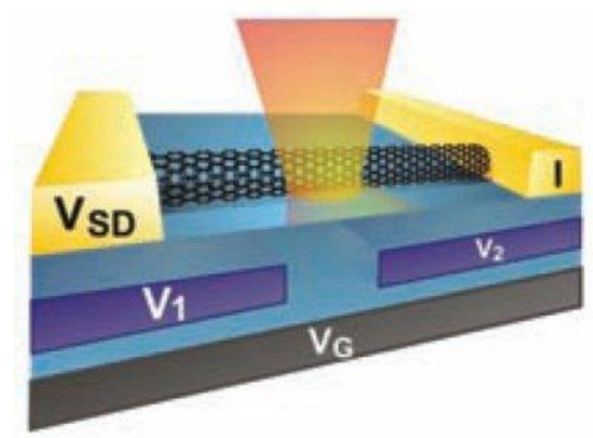
Carbon nanotubes,

- Carbon nanotubes (CNT) are constructed of a hexagonal lattice carbon with excellent mechanical and electronic properties.

- Carbon nanotubes can be used as reasonably efficient photosensitive materials as well as other PV material.

- The efficiencies are still in the 3–4% range but much research is being conducted in this field.



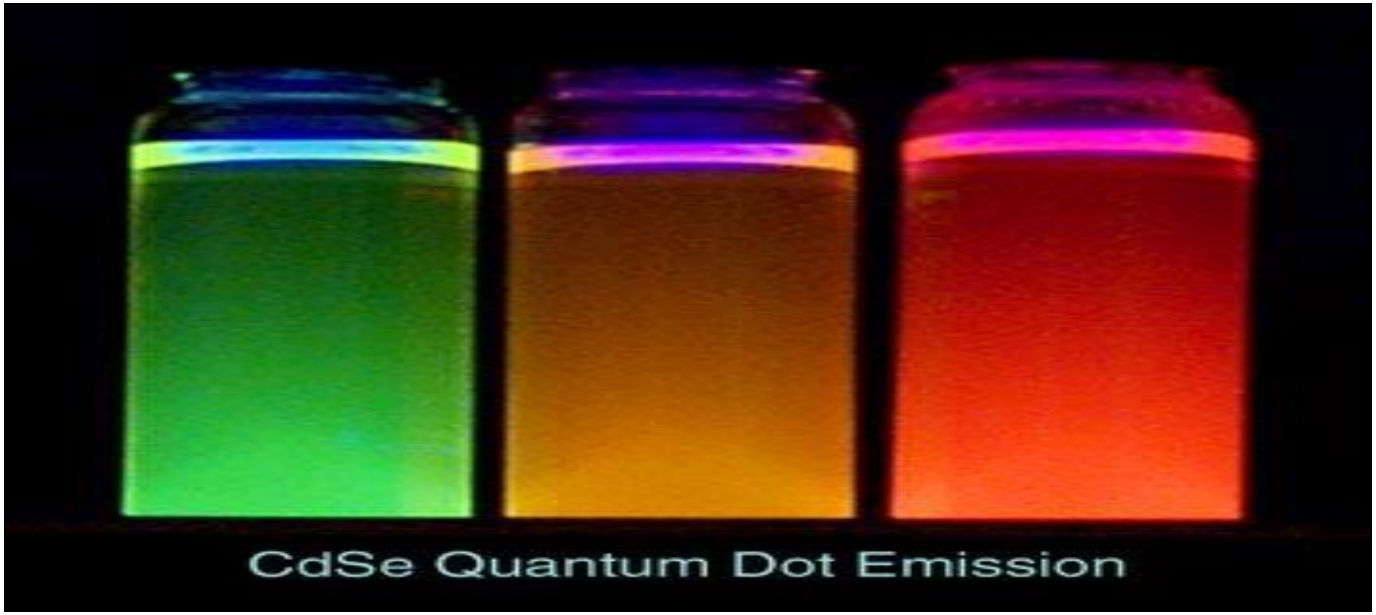


Available Technologies

Nanotechnology

Quantum dots

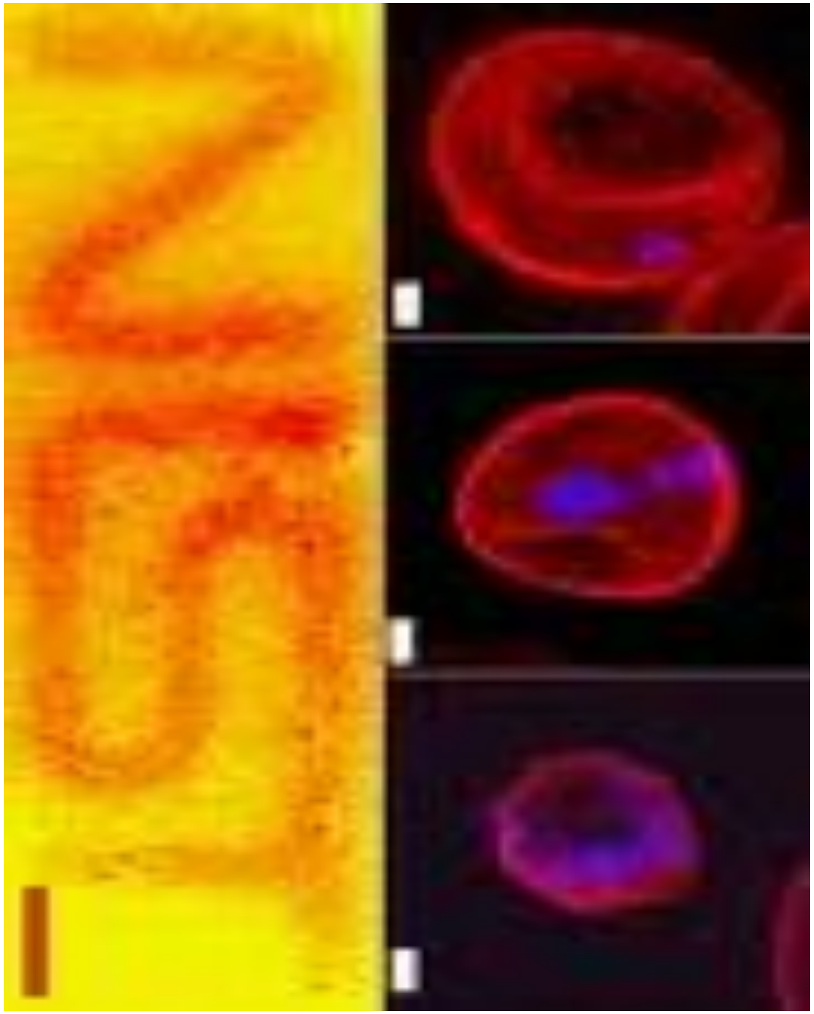
- Quantum dot (QD) metamaterials are a special semiconductor system that consists of a combination of periodic groups of materials molded in a variety of different forms. They are on nanometer scale and have an adjustable band-gap of energy levels performing as a special class of semiconductors.



Available Technologies

Nanotechnology

Quantum dots



•Quantum dot sensitized solar cells (QDSCs) are third-generation photovoltaic devices.

•Theoretically increase efficiency of solar cells up to 44%

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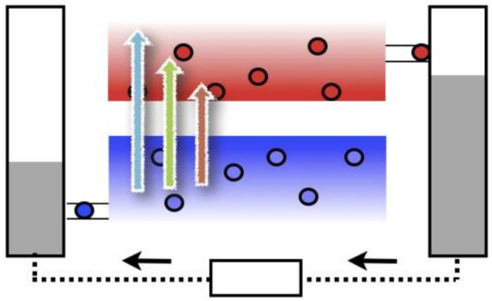
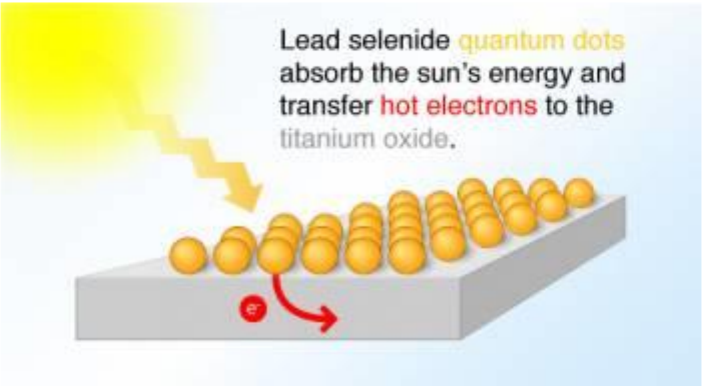
Available Technologies
Nanotechnology

Hot carrier solar cell

- This technique is the most challenging method since it utilizes selective energy contacts to extract light generated by "hot carriers" (HC) (electrons and holes) from semiconductor regions without transforming their extra energies to heat. This is the most novel approach for PV cell production and it allows the use of one absorber material that yields to high efficiency under concentration.

- The efficiency conversion factor reached a limit of 66% which is 52% higher than that of traditional Si PV cell systems and 33% higher than the systems generated using QD principle.





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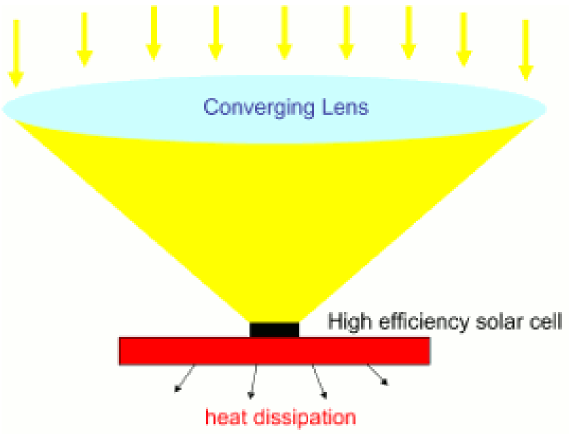
Available Technologies

CPV

Concentrated photovoltaic (CPV), uses mirrors or lenses to ‘concentrate’ or focus light from a relatively broad collection area onto a much smaller area of active semiconductor PV material. These systems show very high cell conversion efficiencies of over 36%.

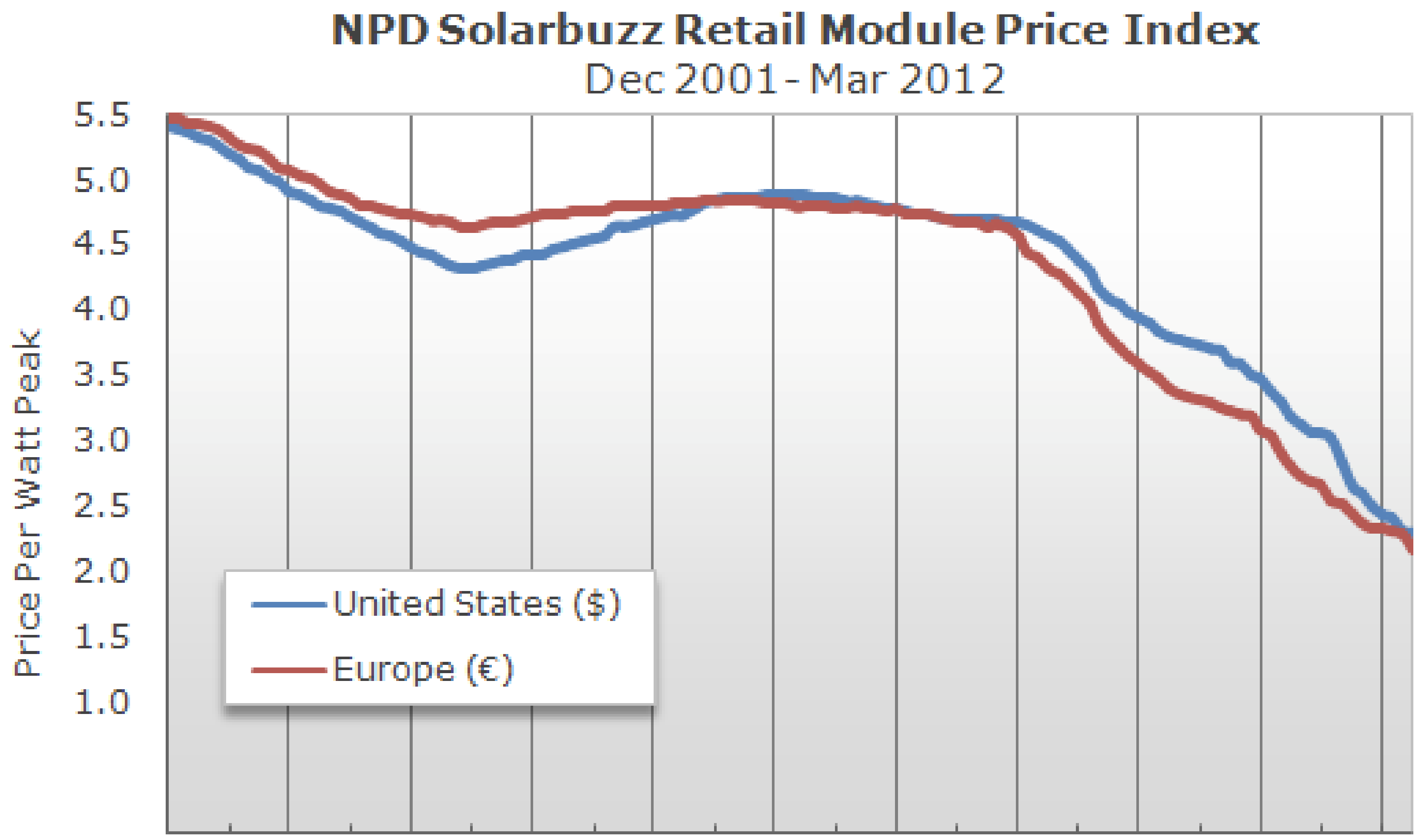


EFFICIENCIES (%)

Technologies	Cell Efficiency (%)	Module Efficiency (%)	
		Laboratory efficiency	Module on market
Monocrystalline silicon	25 ± 0.5	22.7	14–20
Polycrystalline silion	20.4 ± 0.5	16.2	11–15
Amorphous silicon	10.1 ± 0.3	10.4	5–9
CdTe	18.3 ± 0.5	8.3	
CIS	19.3	13.5	9–11
CIGS	19.6 ± 0.6	10.3	

Green et al., 2013; Robert, 2013

COST OF PHOTOVOLTAIC'S

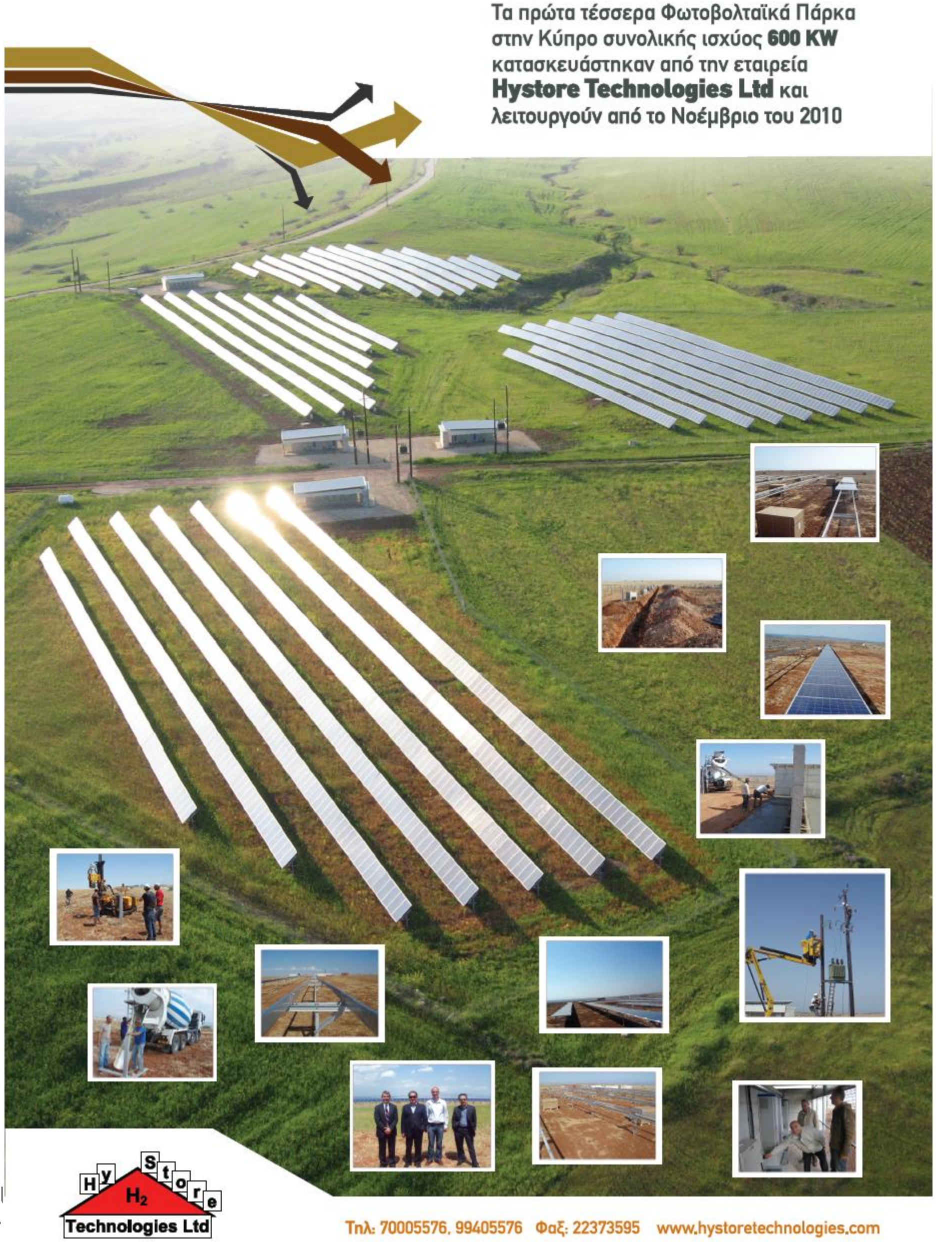


COST OF PHOTOVOLTAIC'S

First Cypriot grid-connected Photovoltaic System (5.25kW) 2005
CAPEX: 32000 EURO or 6.1 euro / Wp

COST OF PHOTOVOLTAIC'S

First PV Parks in Orounta-Cyprus
4X150kW. Capex: 3 euro / Wp



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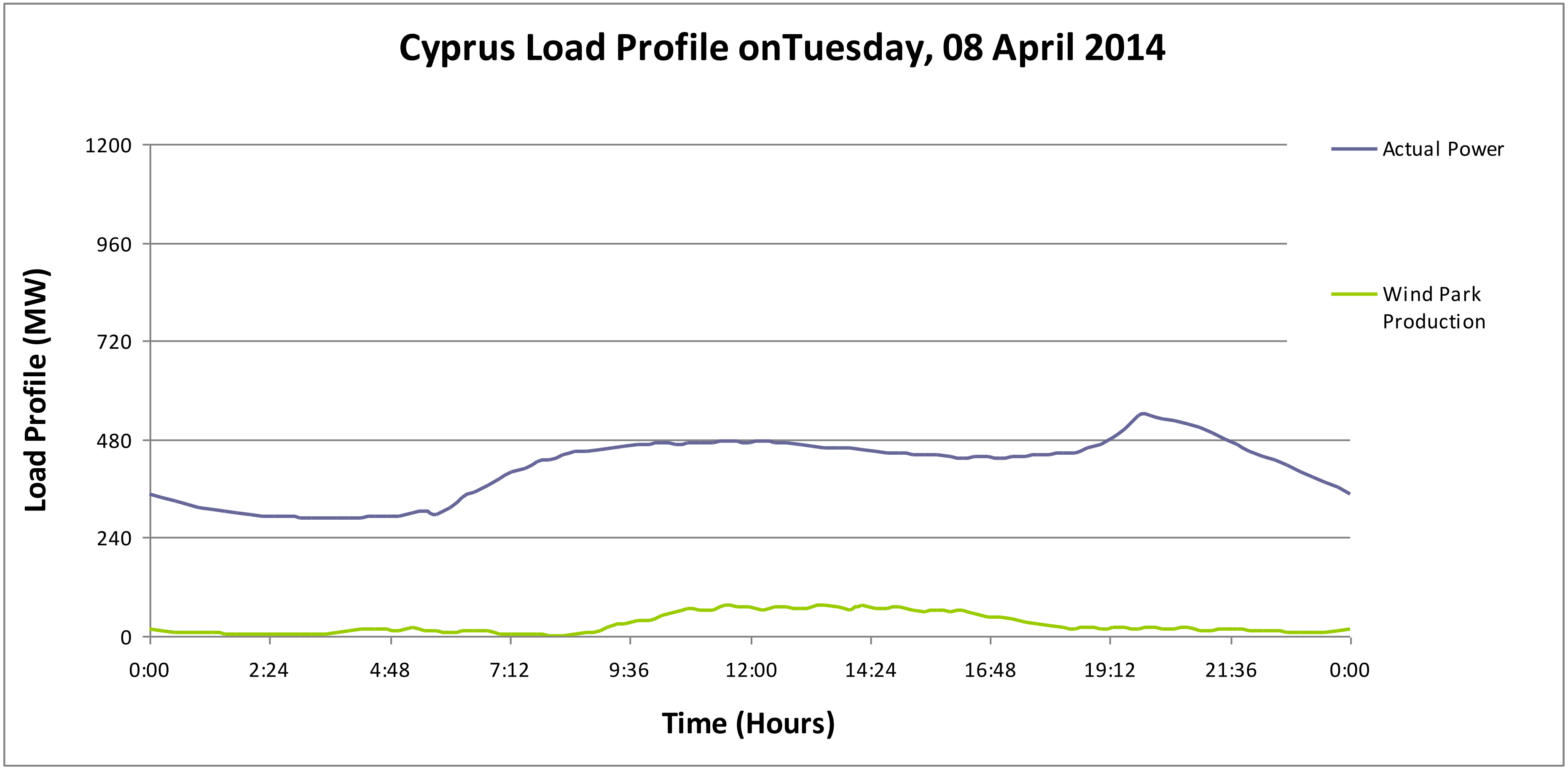
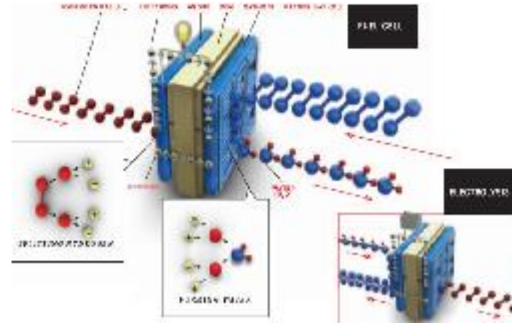
THE NEED TO STORE ELECTRICITY



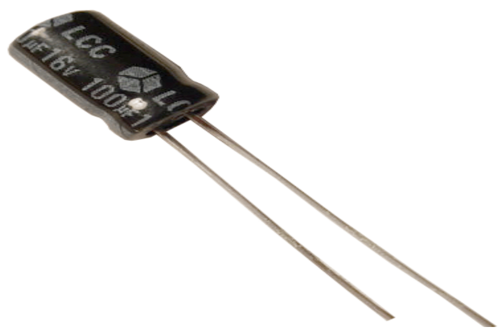
THE NEED TO STORE ELECTRICITY

- Chemical



- Electrochemical

- Electrical



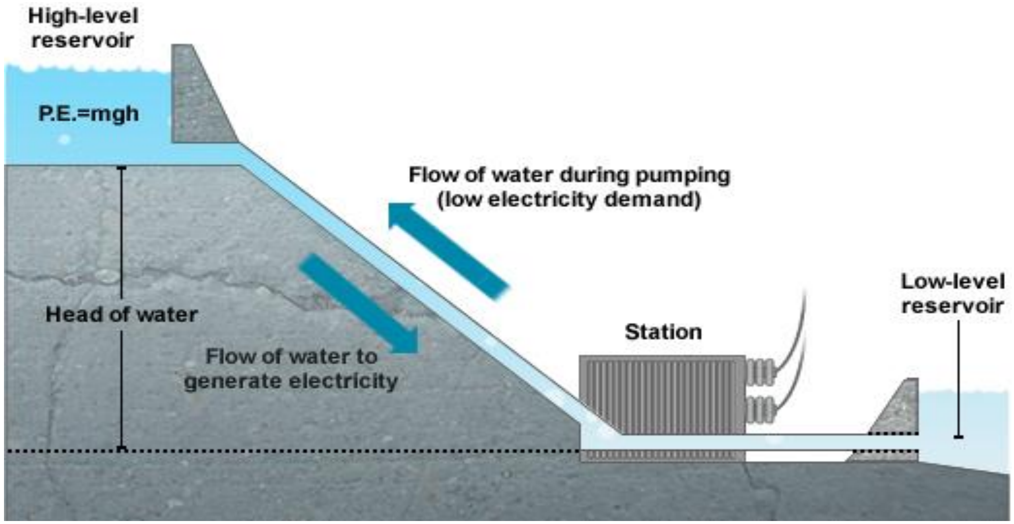
- Thermal

THE NEED TO STORE ELECTRICITY

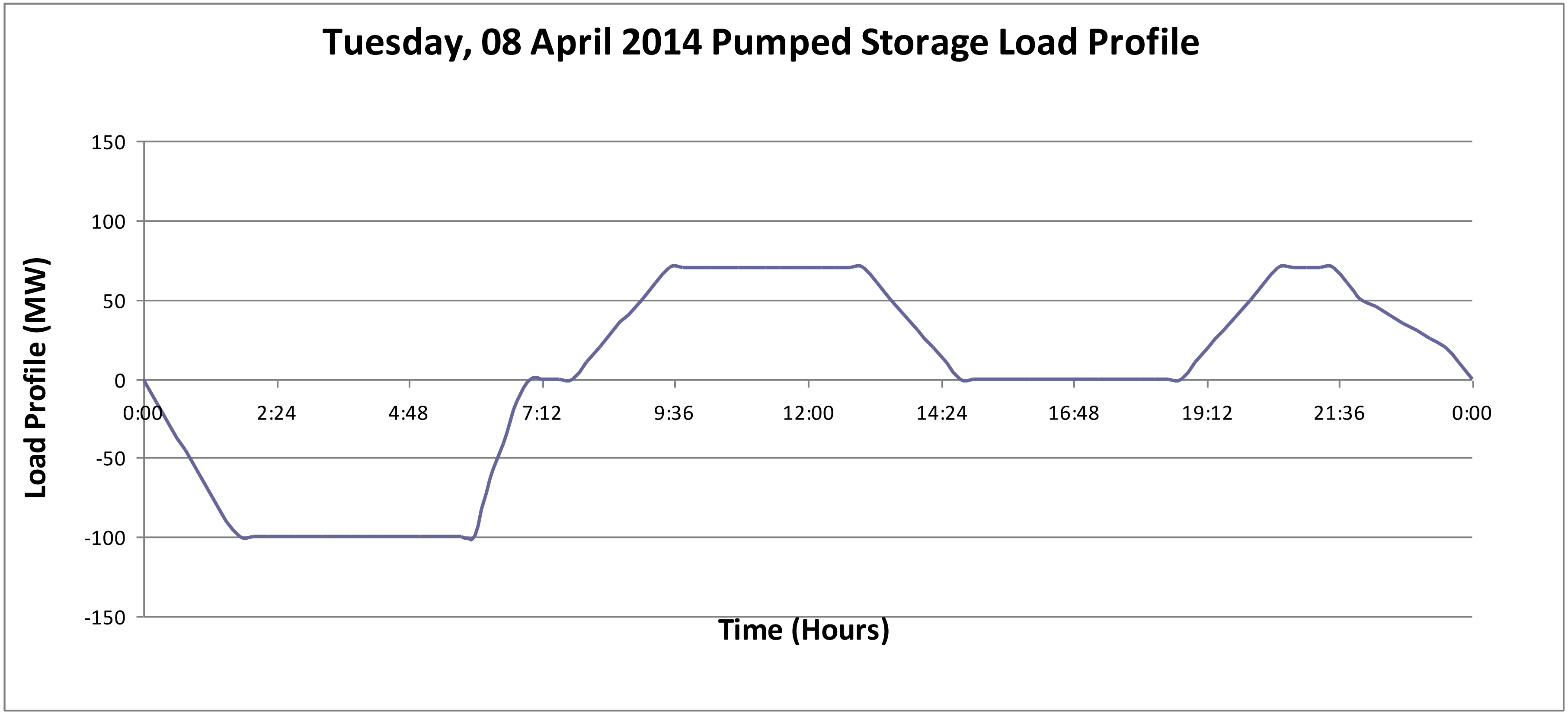
•Mechanical:

Potential energy released on a turbines blades in order to rotate it and produce electricity. The terminology behind this energy conversion is named:

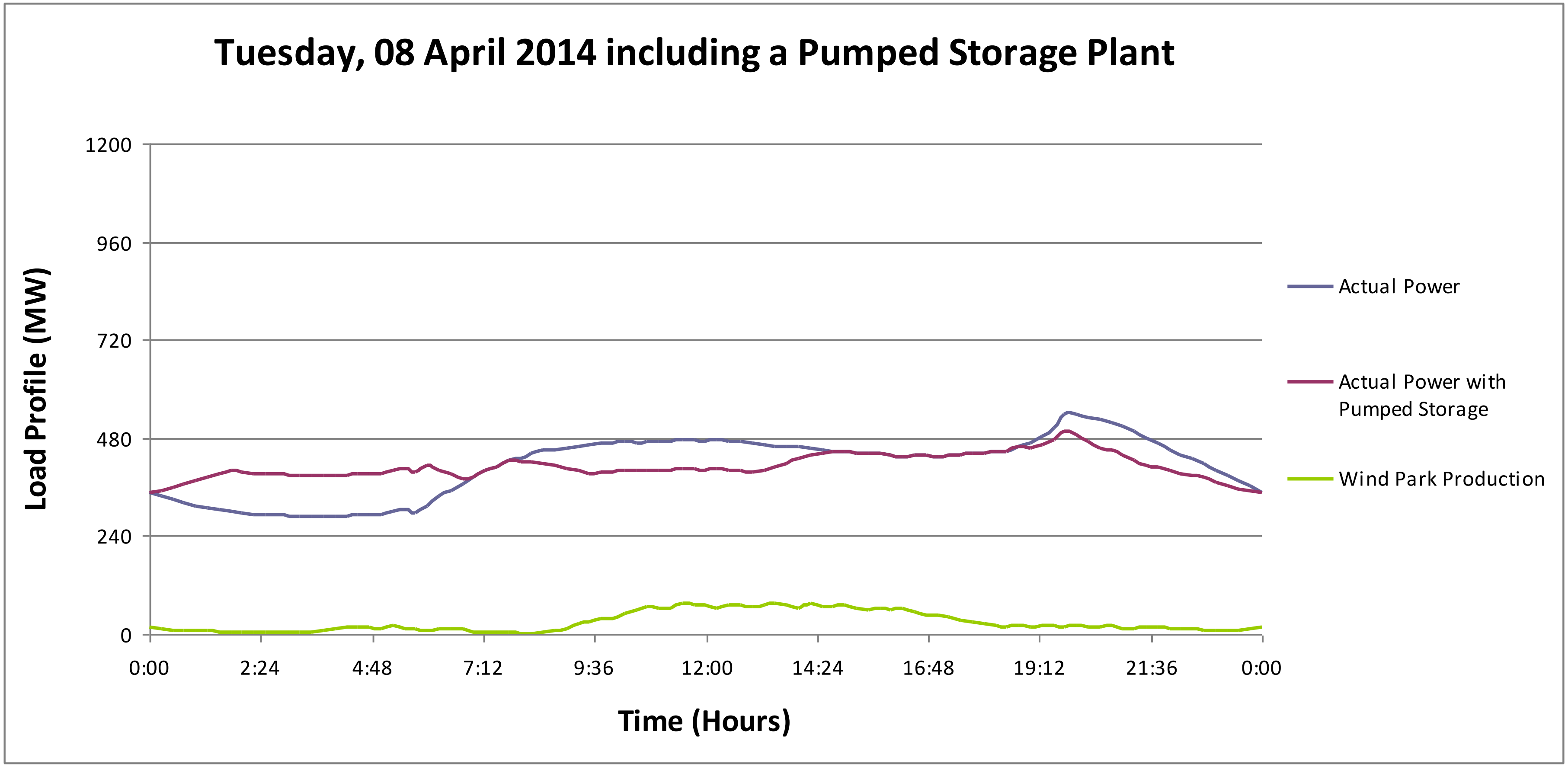
‘Pumped Storage’



THE NEED TO STORE ELECTRICITY



THE NEED TO STORE ELECTRICITY



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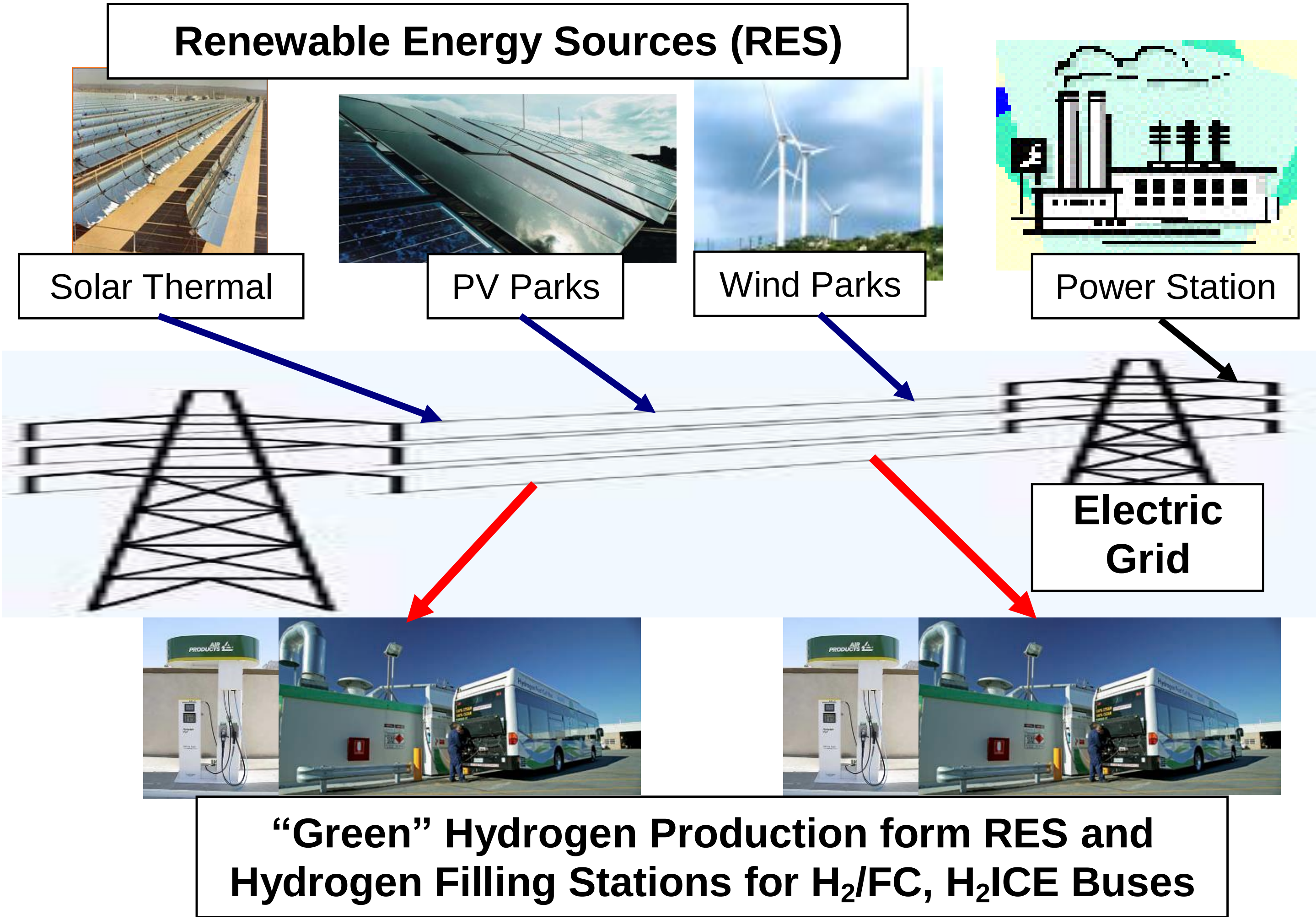
THE NEED TO STORE ELECTRICITY

STORING OF RES ELECTRICITY IN THE FORM OF H2



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Conclusions

- More RES are needed.
- PV's are a suitable technology
- Storage of RES electricity is essential.

Thanks for your attention

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