Concentrator Photovoltaics

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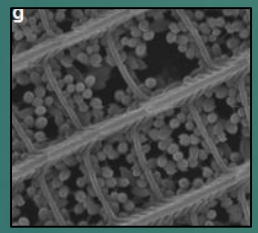

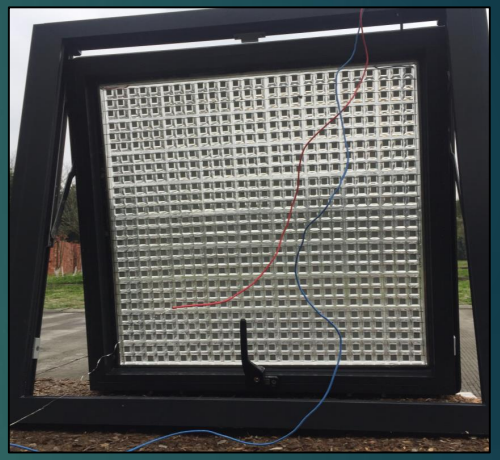

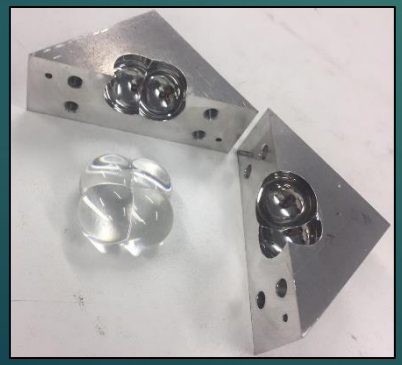

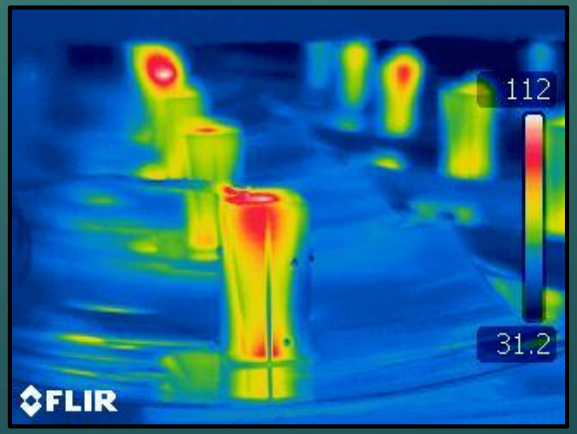

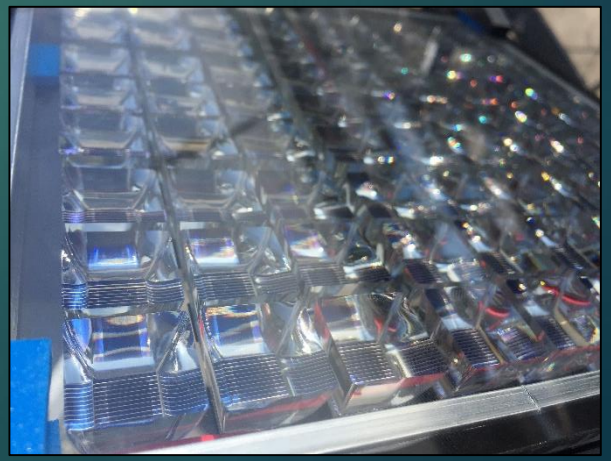

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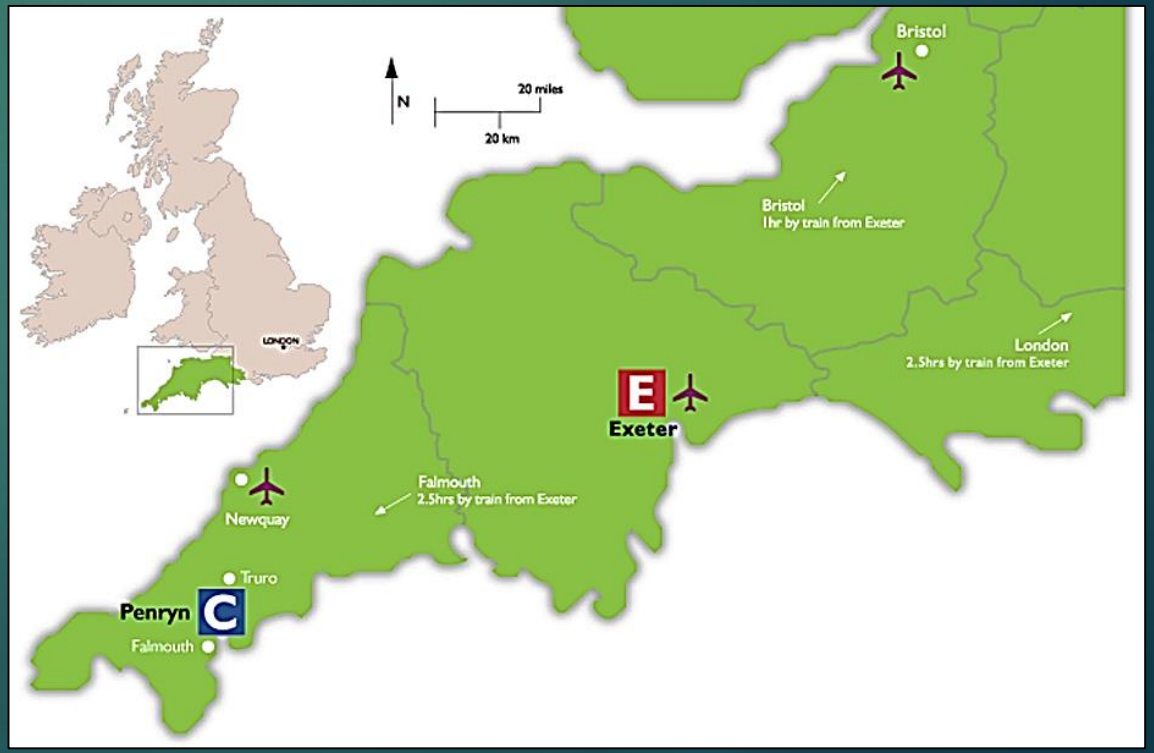
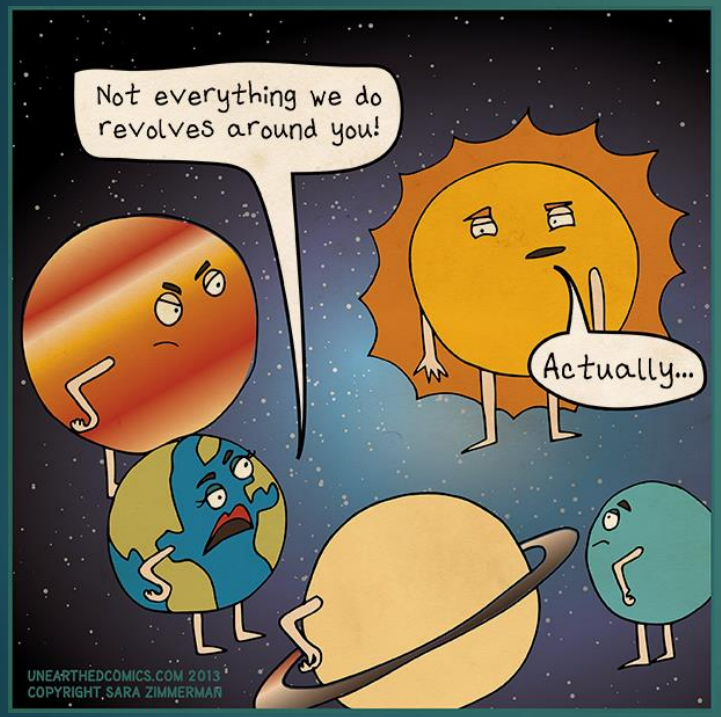


Overview

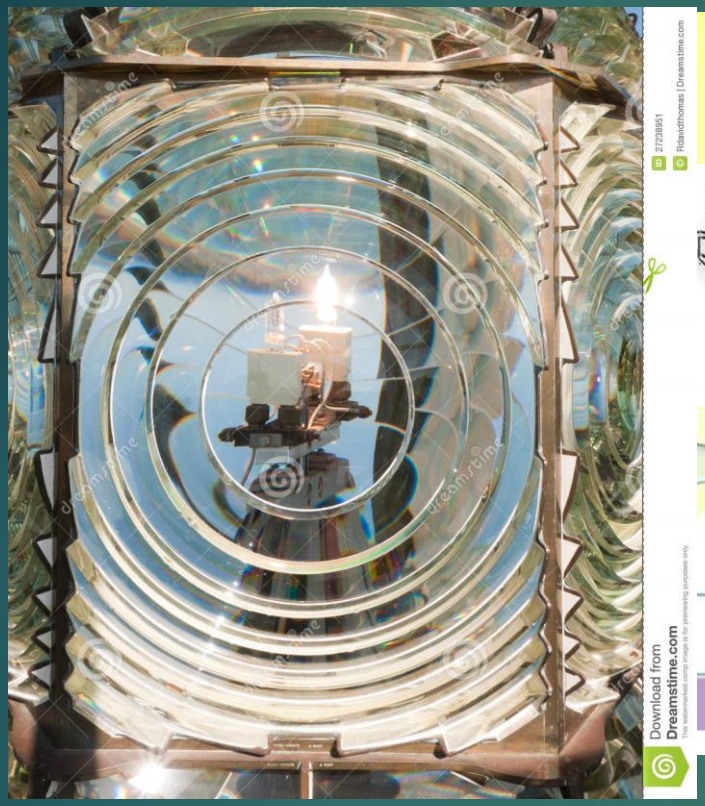


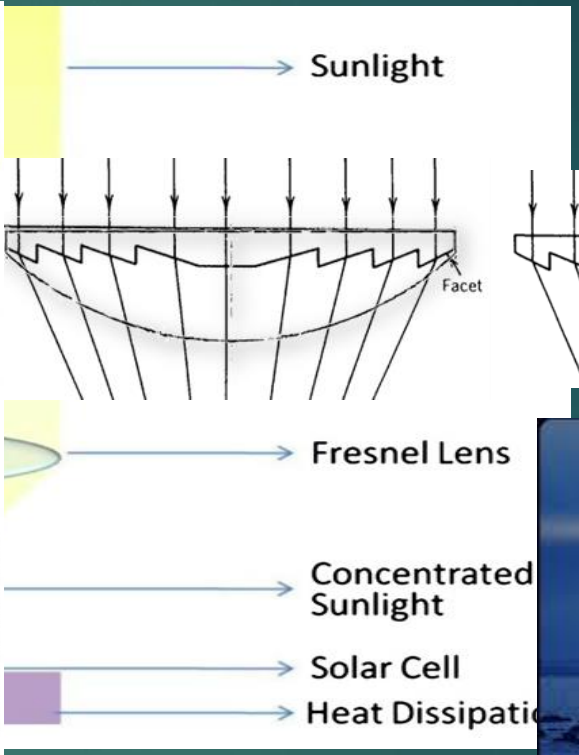
1. What are Solar Concentrators (CPV)?
    1. Main Types of CPV
    2. CPV parts and groups
2. Why CPV?
    1. Solar Cell Efficiencies
3. Optics for CPV
    1. Reflection, Refraction and Scattering
4. My Research
    1. Weight reduction
    2. Novel materials and Surface Structures
    3. Biomimicry
        1. (Interdisciplinary Research)
    4. Art and Energy
5. Costs of CPV
6. Progress of CPV
7. UNSW Research and Collaborations

What are solar concentrators?

- Solar Concentrators **use optics** such as mirrors and lenses to **increase the sunlight** incident on solar photovoltaic or solar thermal devices.
- **Increase** the **power output** by increasing the power input.
- **Reduce** the photovoltaic **material required**.

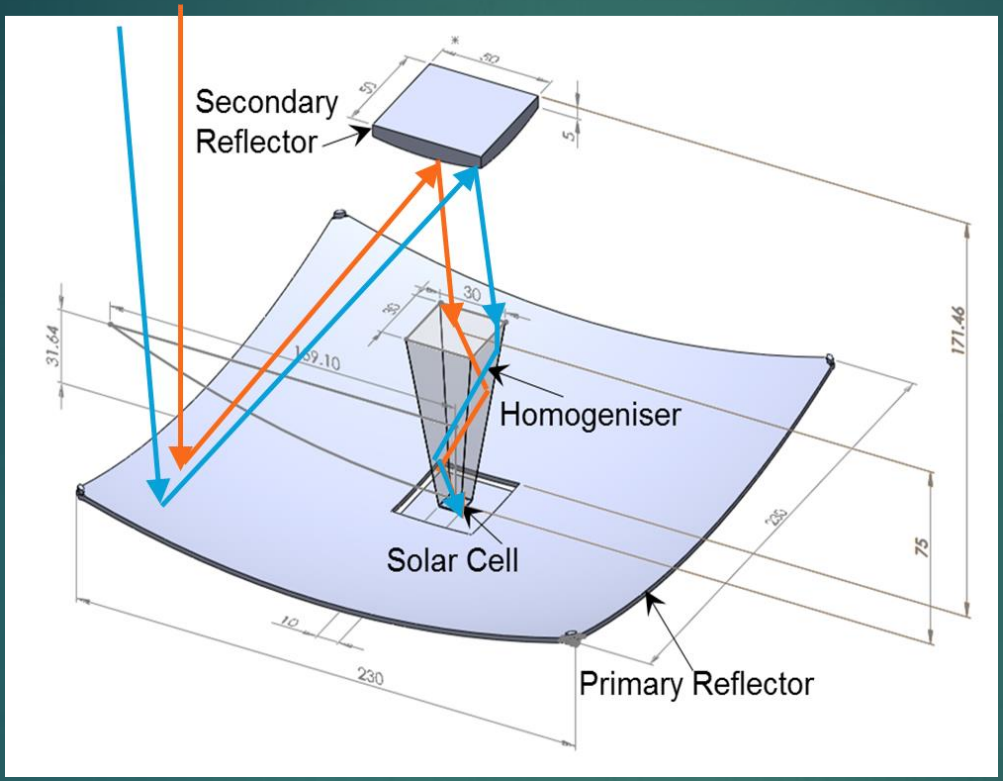
Fresnel Lens?





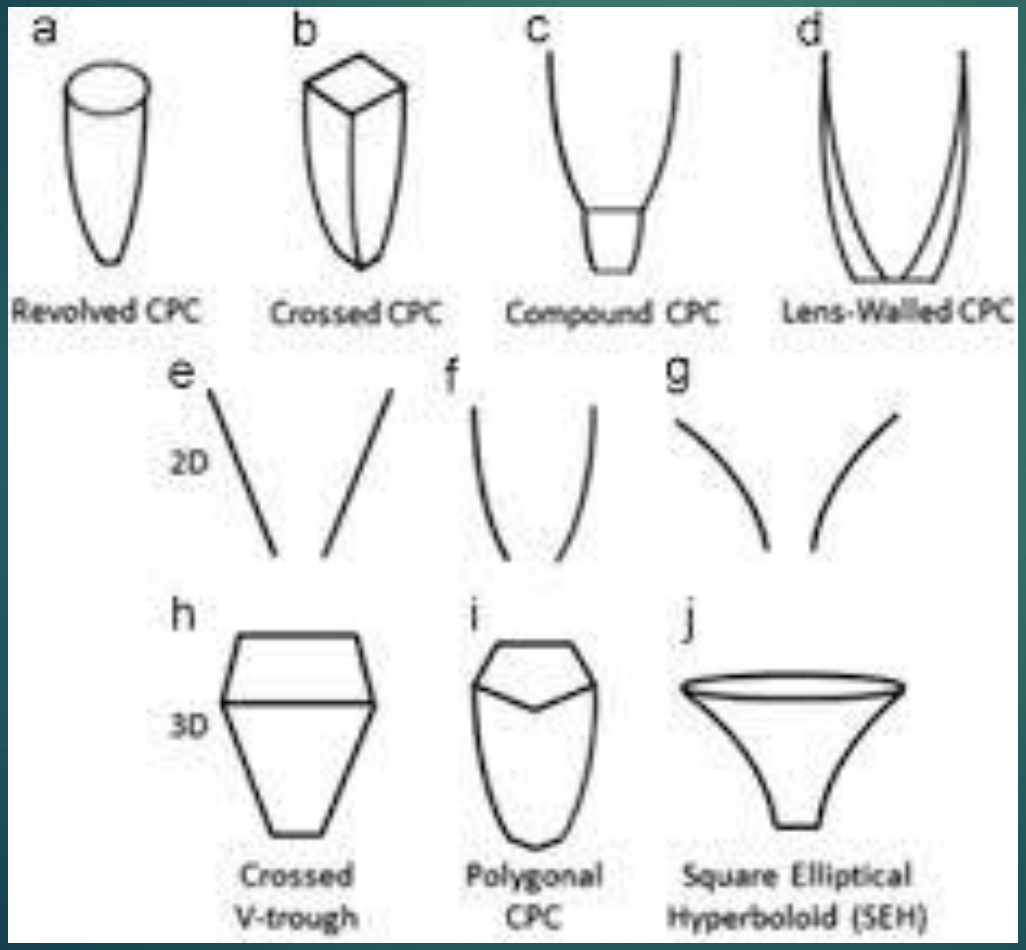
- Module is typically mounted on a tracker
- Typically system has built in power conditioning
- CPV systems are often rated based on their AC power
- Secondary optics are there to increase acceptance angle

Cassegrain?

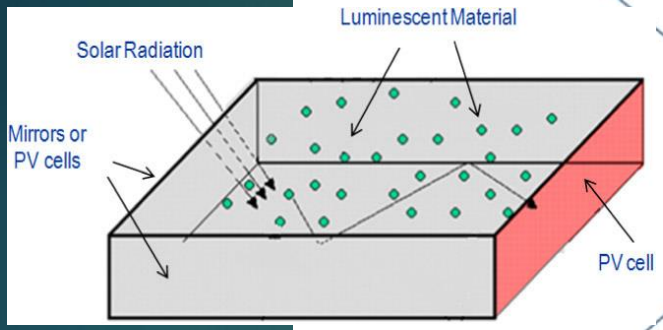


- High concentration ratios
- Uses a lot of optics/stages/interfaces

Low Concentration Optics



Solar Concentrator Grouping



CPV Optics

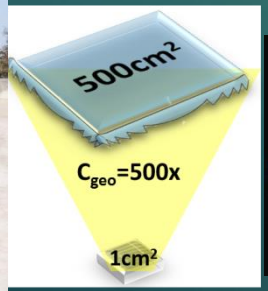
Concentration Ratio
- Low (<10 suns)
- Medium (10-100 suns)
- High (100-2000 suns)
- Ultrahigh (>2000 suns)

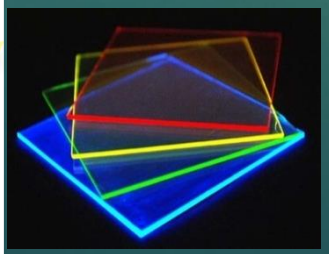
Geometry
- 1 stage, 2 stage…
- Parabolic
- Hyperbolic
- Elliptical
- Dish
- Trough

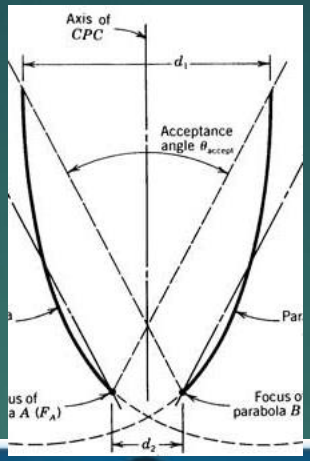
Tracking Method
- 2D / single-axis / Linear
- 3D / dual-axis / Point
- Stationary
- Quasi-Static

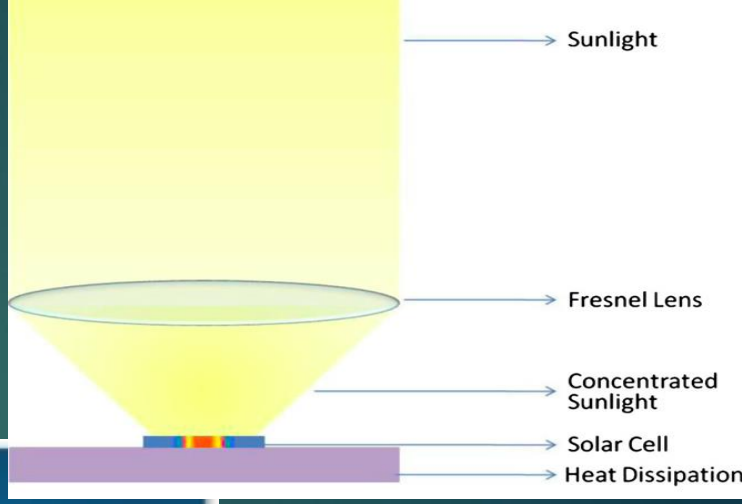
Primary Optic
- Reflective e.g. Cassegrain
- Refractive e.g. Fresnel Lens
- Luminescent

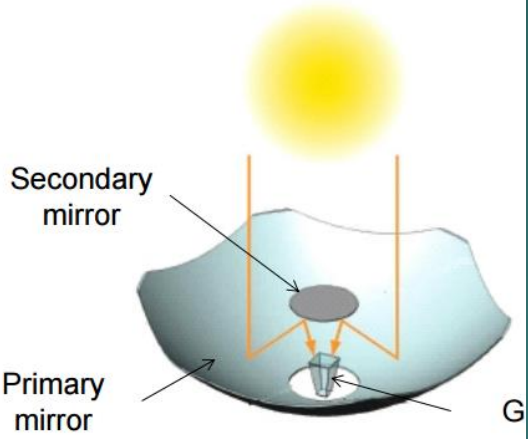
Secondary Optic
- Conic reflector
- Light guide/ Homogeniser
- CPC

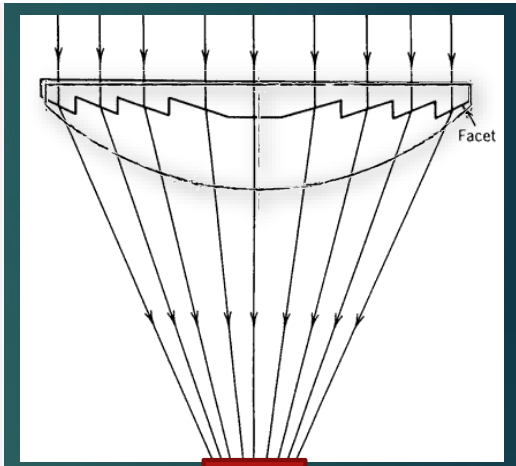


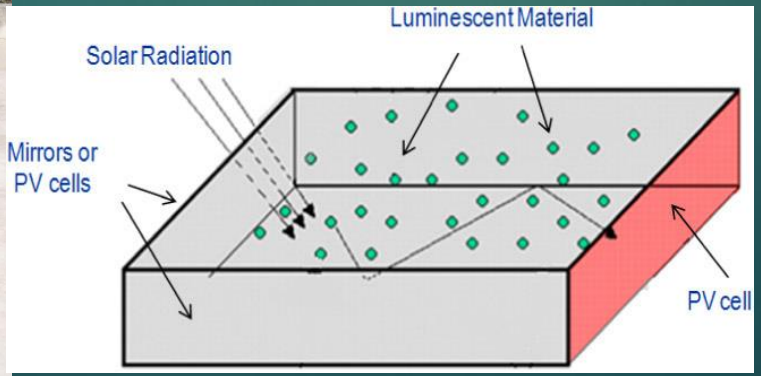


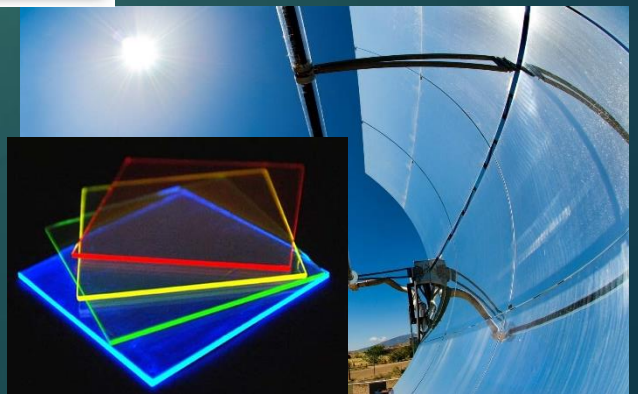

Axis of CPC
d_1
Acceptance angle θ_{accept}
d_2


Sunlight
Fresnel Lens
Concentrated Sunlight
Solar Cell
Heat Dissipation

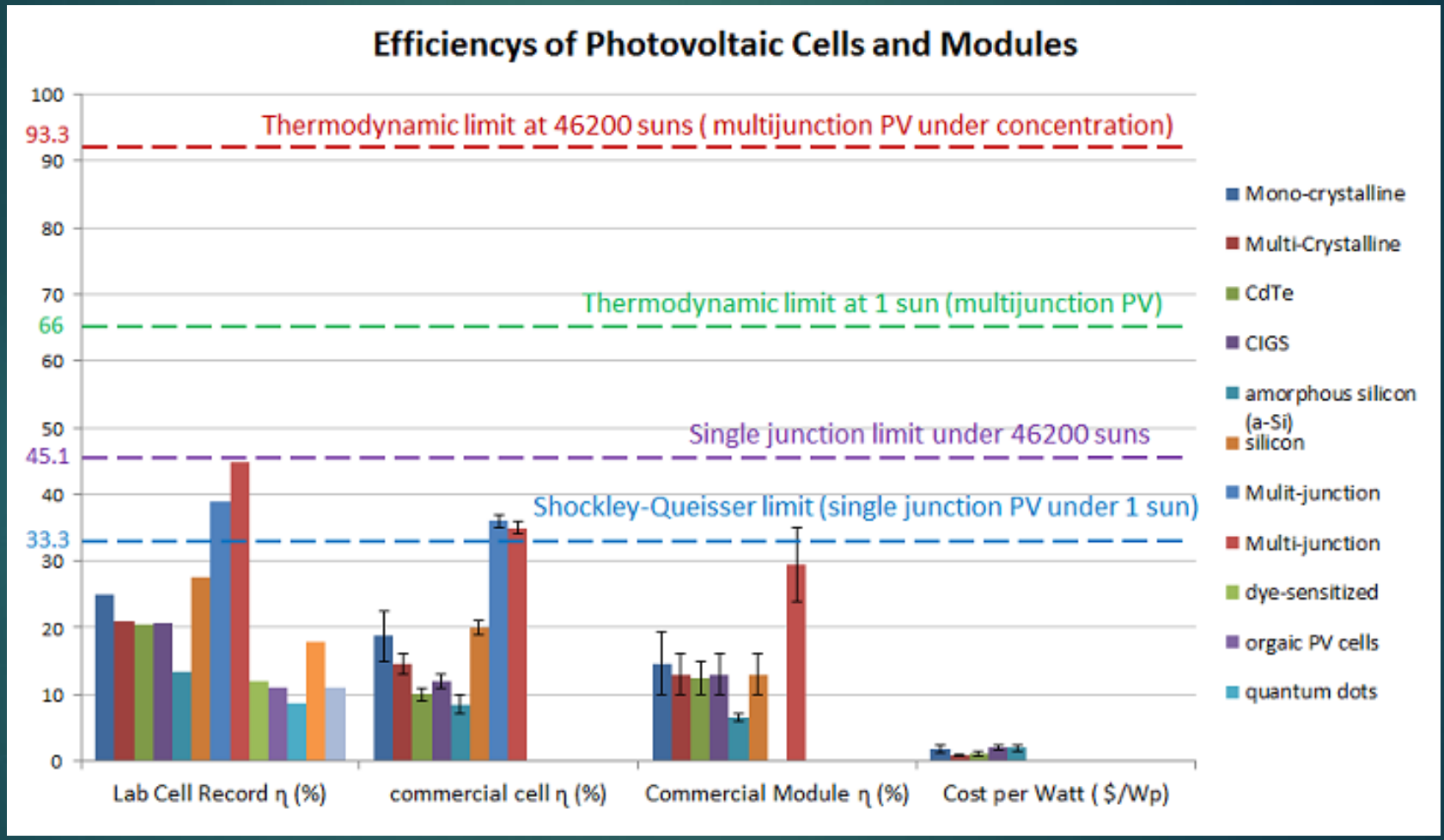

Secondary mirror
Primary mirror

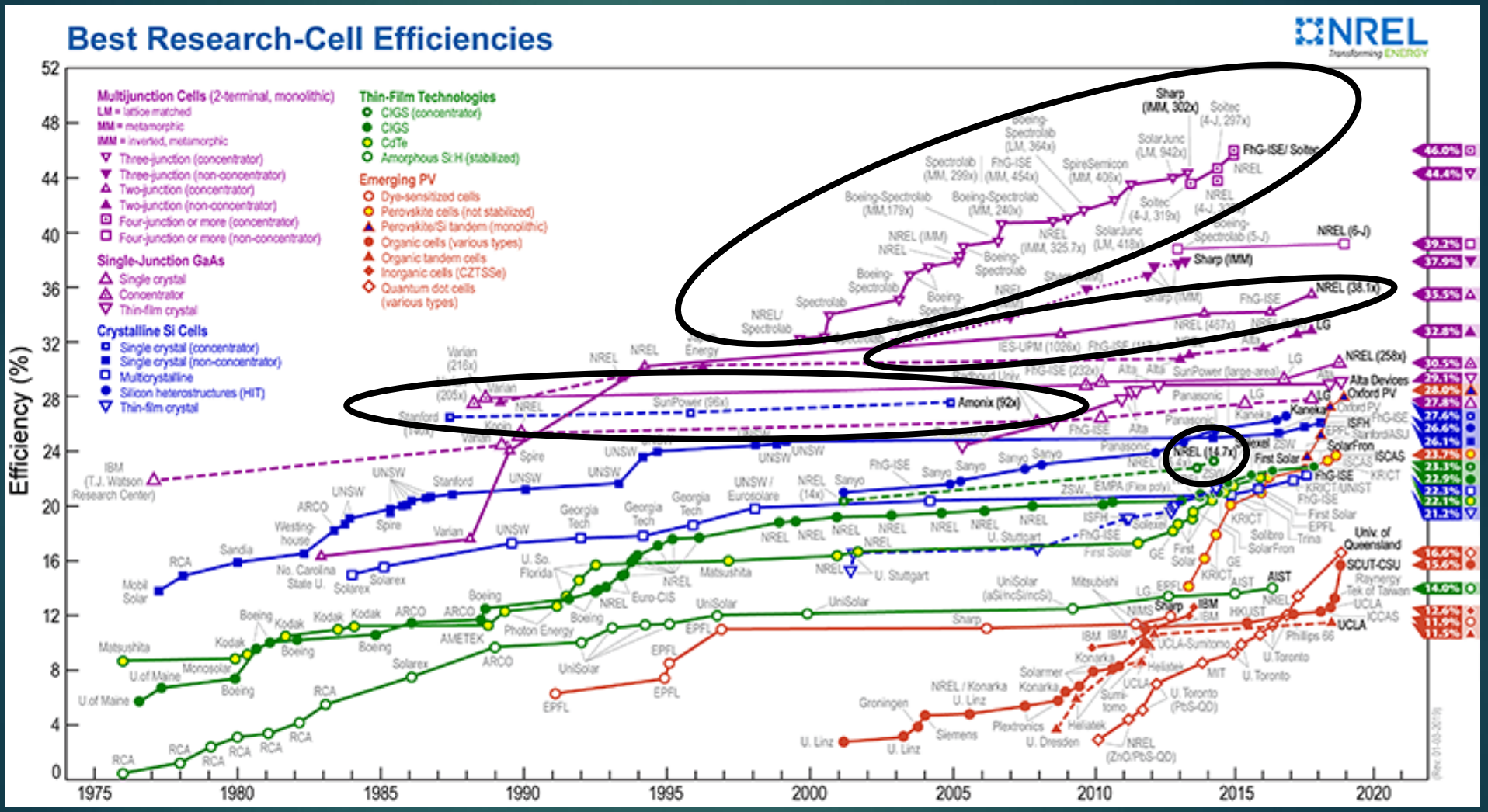

Facet
Cell


Luminescent Material
Solar Radiation
Mirrors or PV cells
PV cell

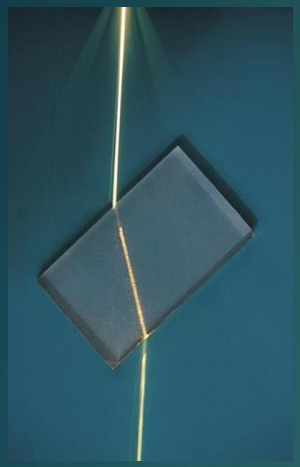


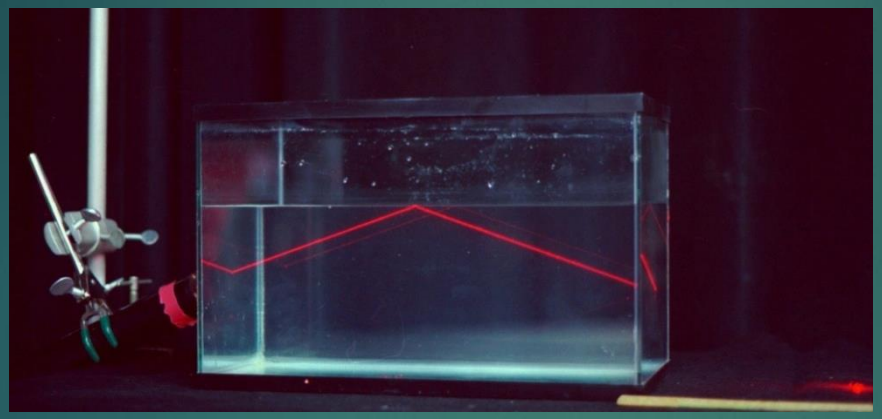
Why CPV?
-solar cell efficiencies

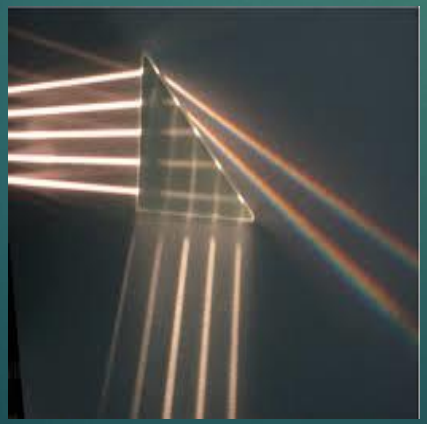


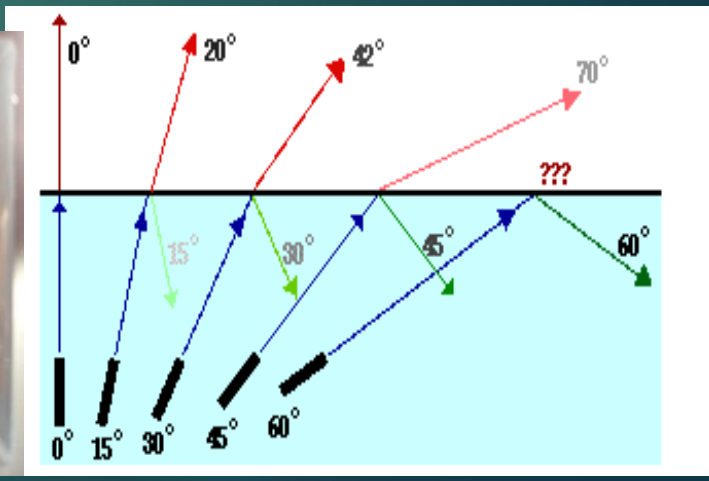

Best Research-Cell Efficiencies
NREL
Transforming ENERGY
Efficiency (%)
Multijunction Cells (2-terminal, monolithic)
LM = lattice matched
MM = metamorphic
IMM = inverted, metamorphic
Three-junction (concentrator)
Three-junction (non-concentrator)
Two-junction (concentrator)
Two-junction (non-concentrator)
Four-junction or more (concentrator)
Four-junction or more (non-concentrator)
Single-Junction GaAs
Single crystal
Concentrator
Thin-film crystal
Crystalline Si Cells
Single crystal (concentrator)
Single crystal (non-concentrator)
Multicrystalline
Silicon heterostructures (HIT)
Thin-film crystal
Thin-Film Technologies
CIGS (concentrator)
CIGS
CdTe
Amorphous Si:H (stabilized)
Emerging PV
Dye-sensitized cells
Perovskite cells (not stabilized)
Perovskite/Si tandem (monolithic)
Organic cells (various types)
Organic tandem cells
Inorganic cells (CZTSSe)
Quantum dot cells (various types)
Sharp (IMM, 302x)
Soitec (4-J, 297x)
FhG-ISE/ Soitec
NREL (6-J)
Sharp (IMM)
NREL (38.1x)
LG
NREL (258x)
Alta Devices
Oxford PV
Kaneka
ISFH
SolarFron
ISCAS
First Solar
Univ. of Queensland
SCUT-CSU
AIST
UCLA
Amonix (92x)
NREL (14.7x)
46.0%
44.4%
39.2%
37.9%
35.5%
32.8%
30.5%
29.1%
28.8%
27.8%
27.6%
26.6%
26.1%
25.7%
23.3%
22.9%
22.3%
22.1%
21.2%
16.4%
15.6%
14.0%
12.6%
11.9%
11.5%

Optics



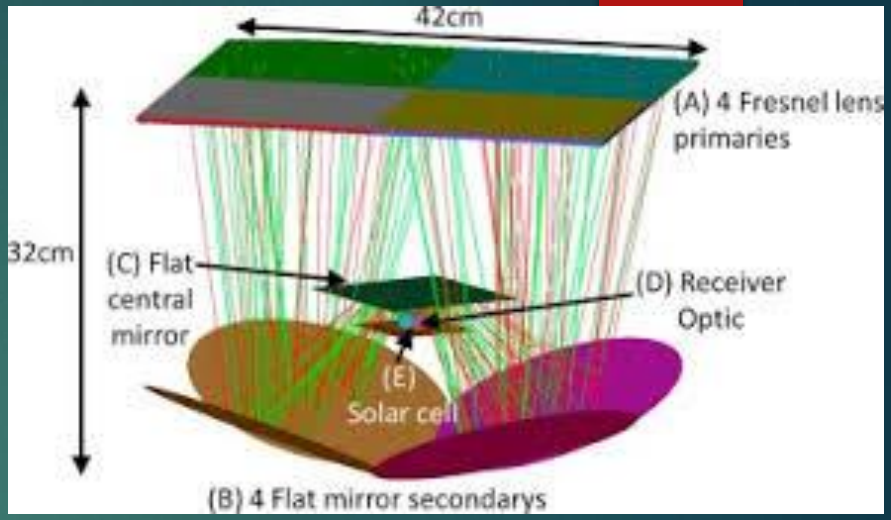


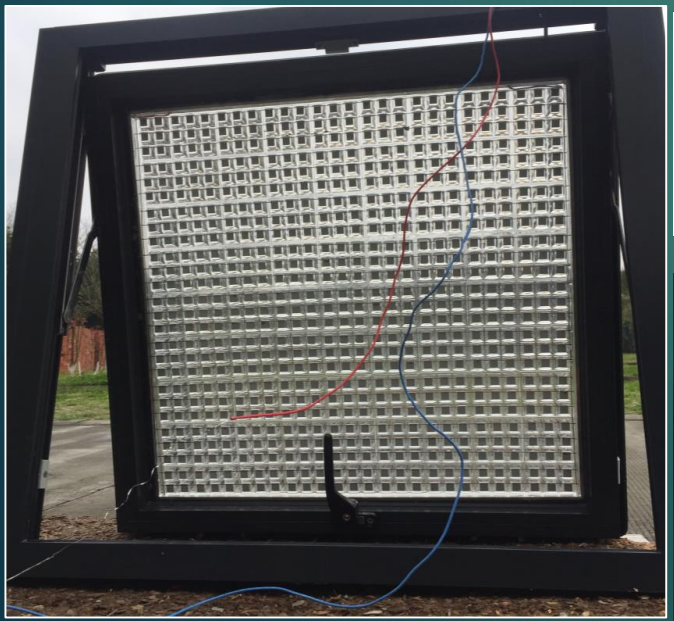


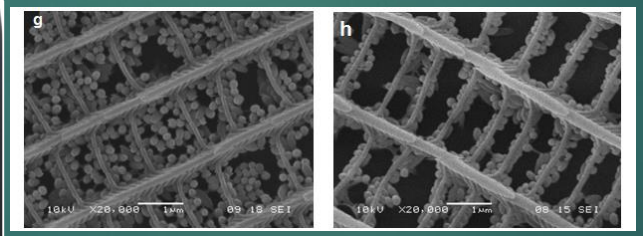


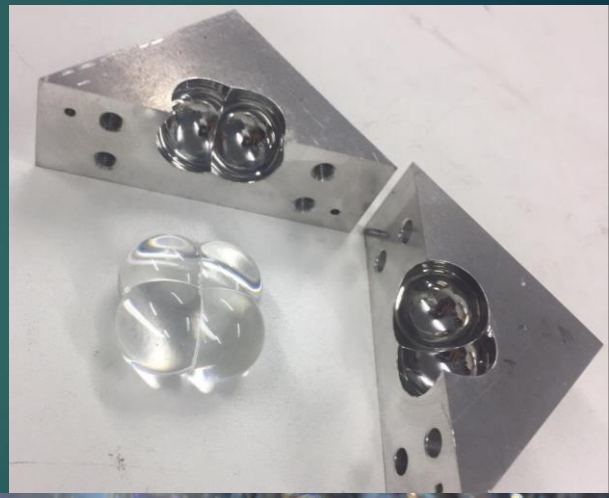
My research

- Reducing weight
- Novel Materials and Surface structures
- Interdisciplinary Research
- Art and Energy



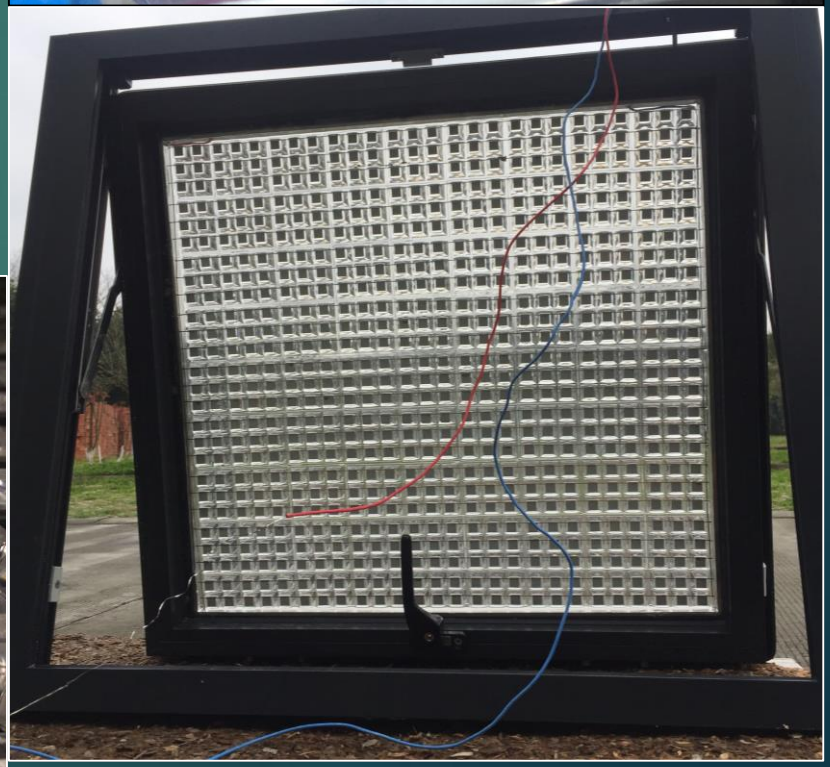


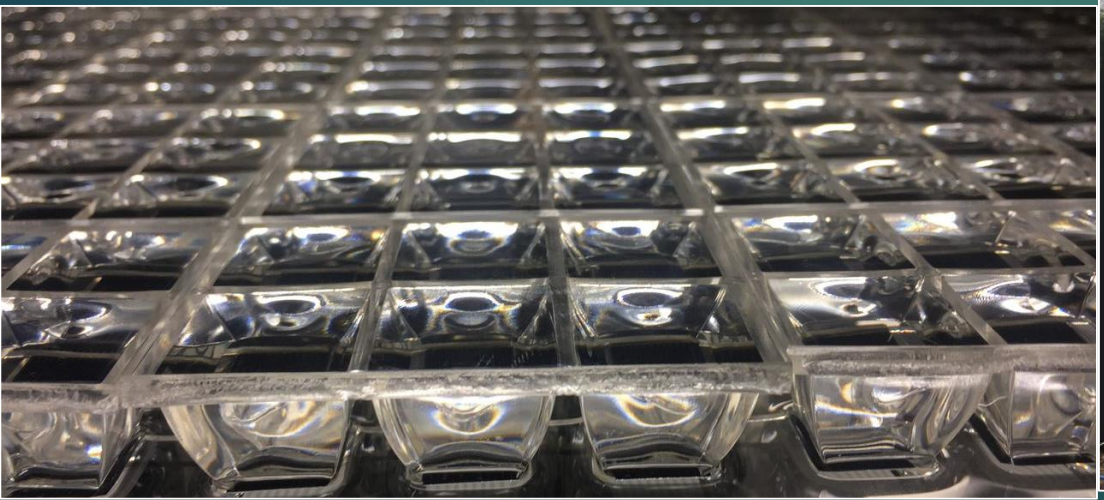




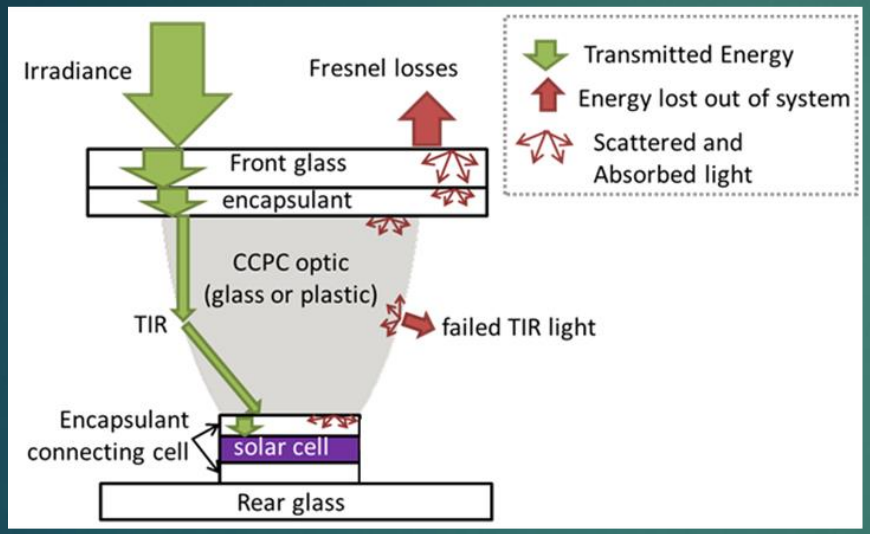
Embedded Plastic Optics

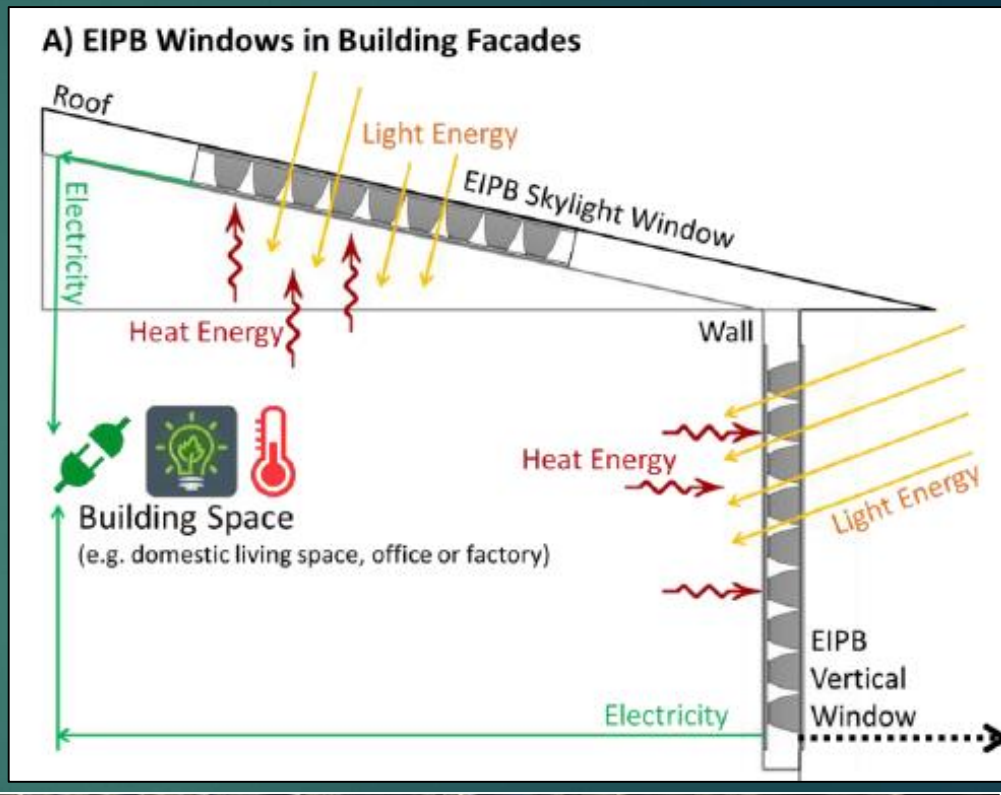
- Reducing weight
- Novel Materials and Surface structures
- Interdisciplinary Research
- Art and Energy



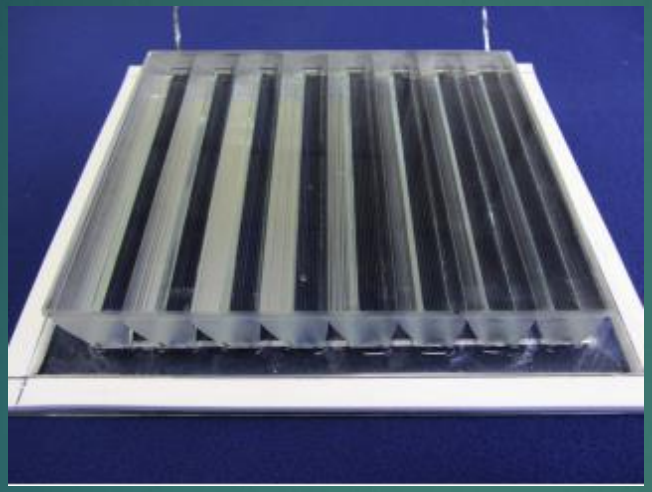


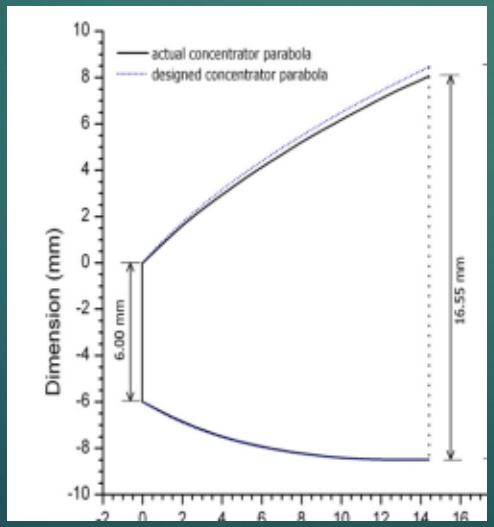
Embedded Systems

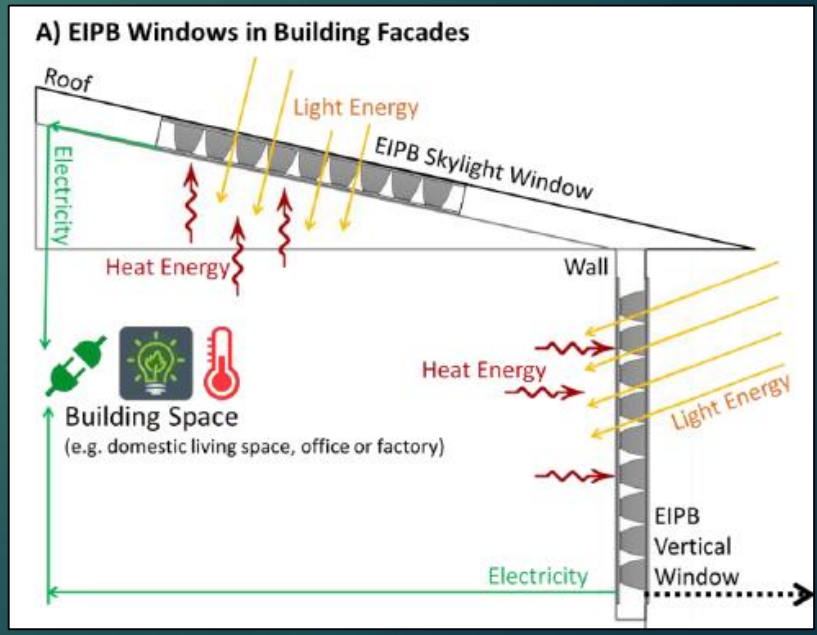




2D Embedded Systems

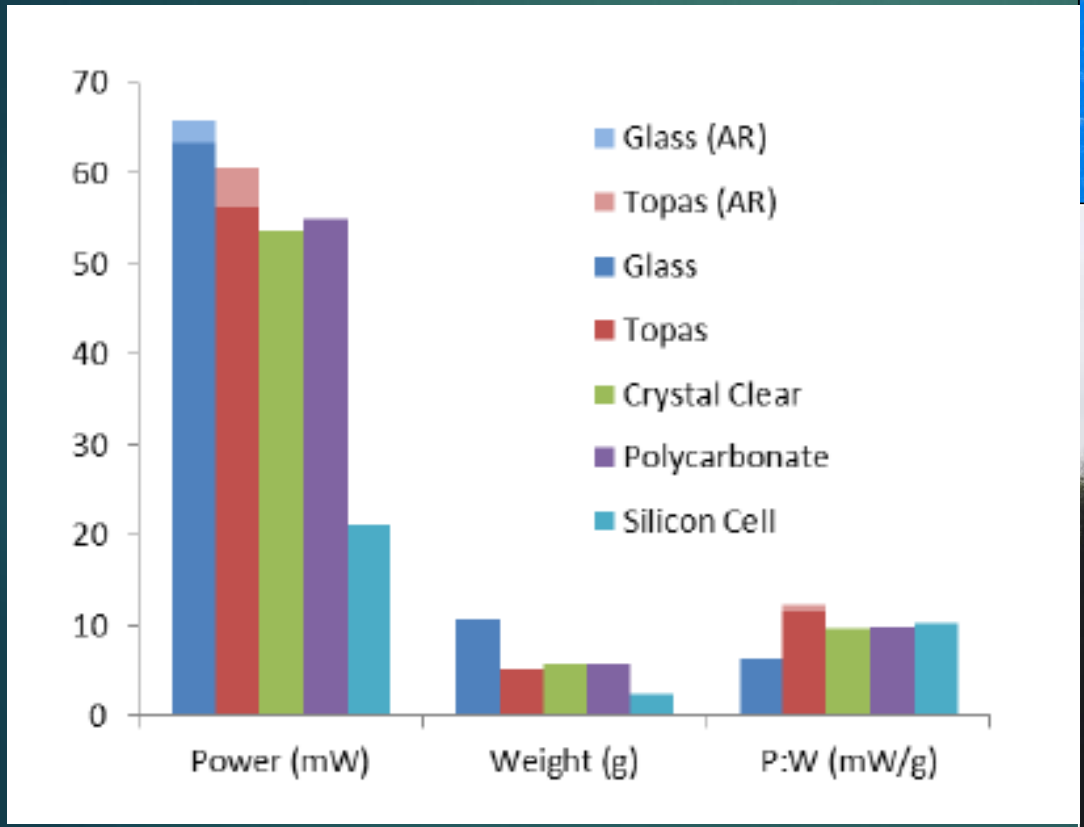


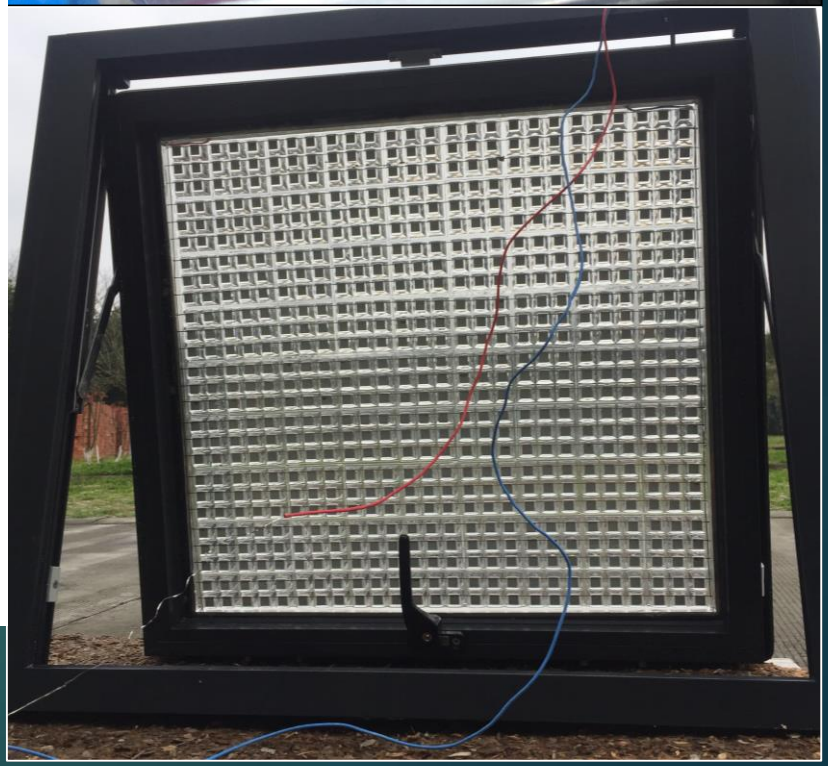




Plastic Optics

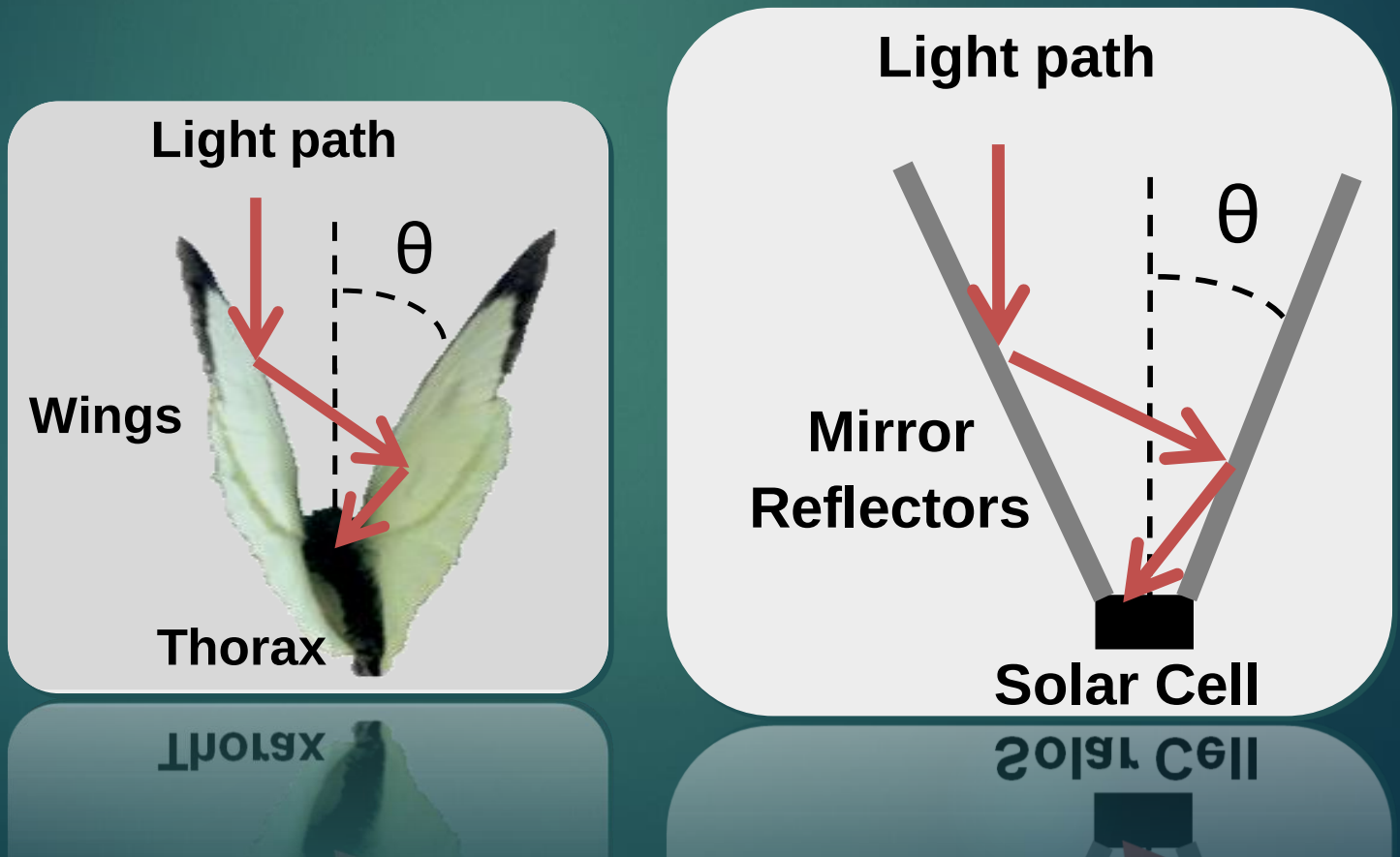
- Higher Power to weight Ratio



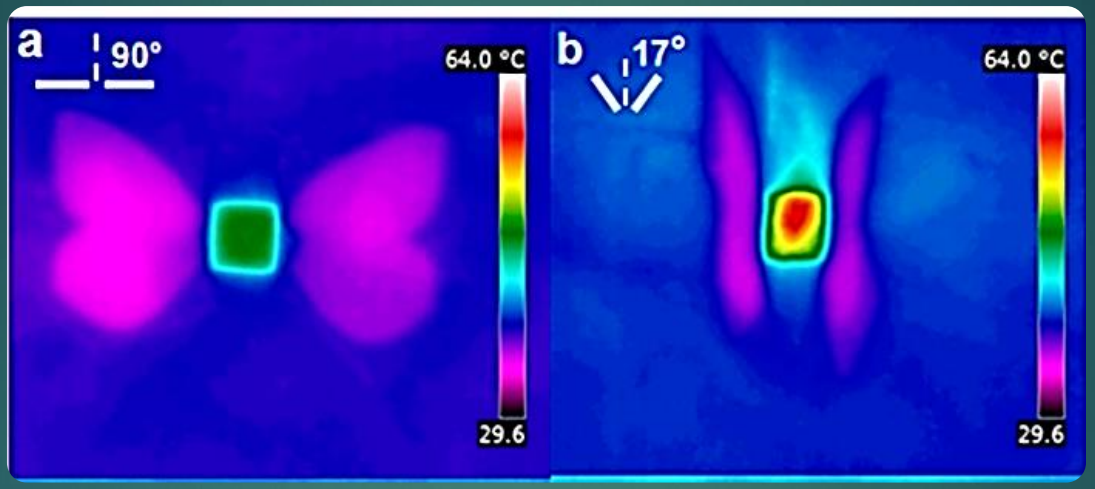


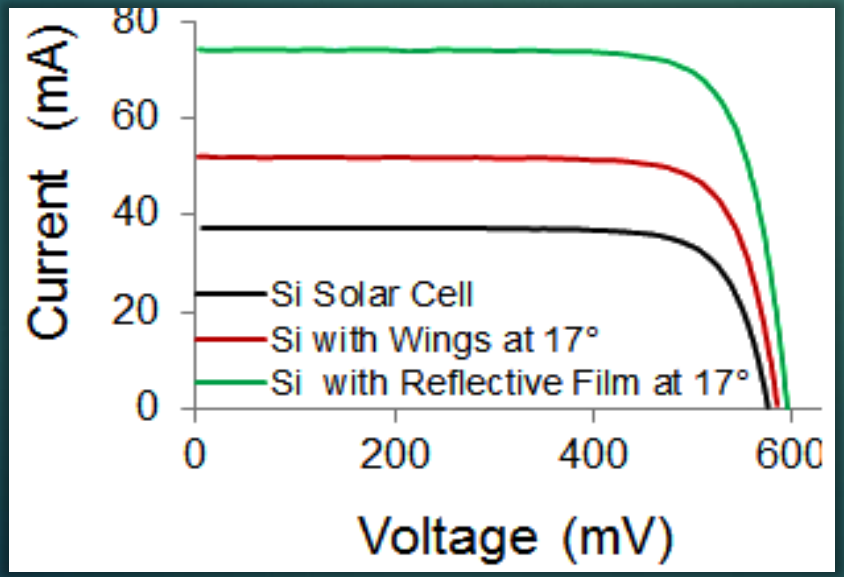
Biomimicry of Butterflies

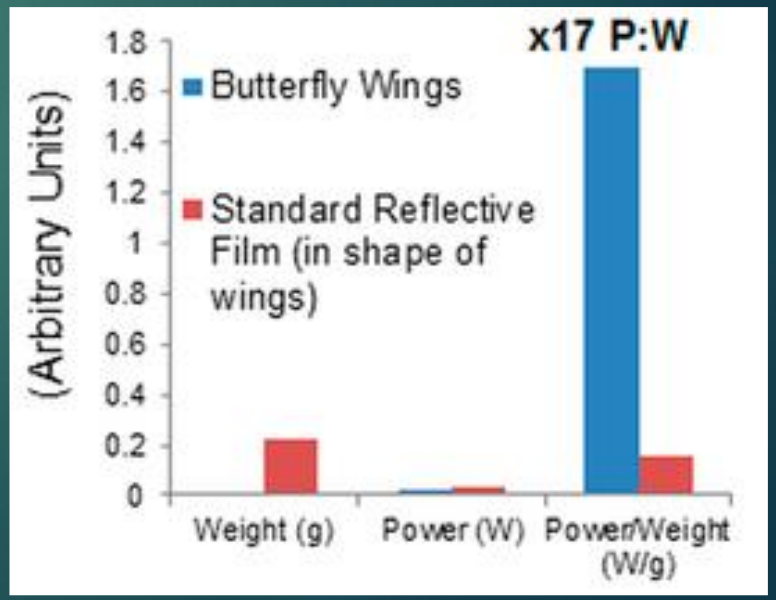
- The Pierids heat their flight muscles faster and fly first.
- Due to V-shaped basking position?



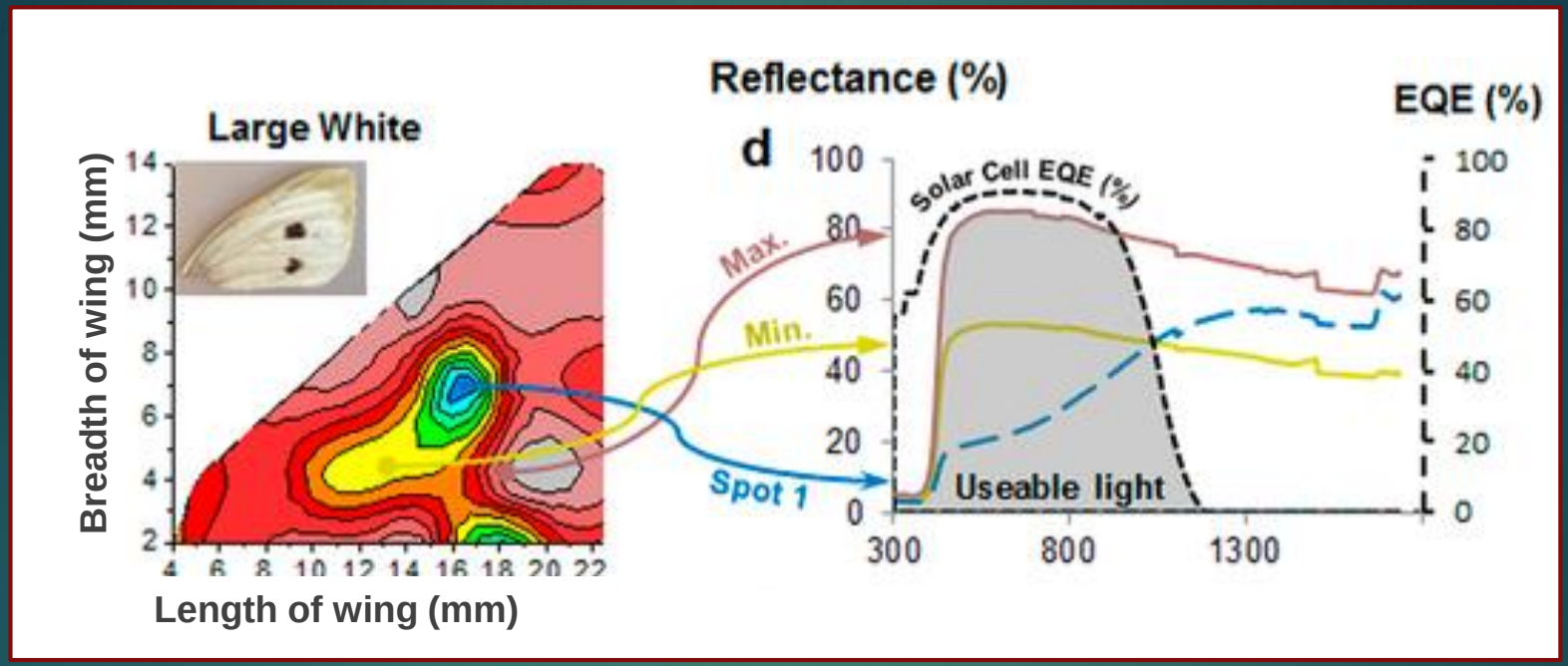
Biomimicry of Butterflies

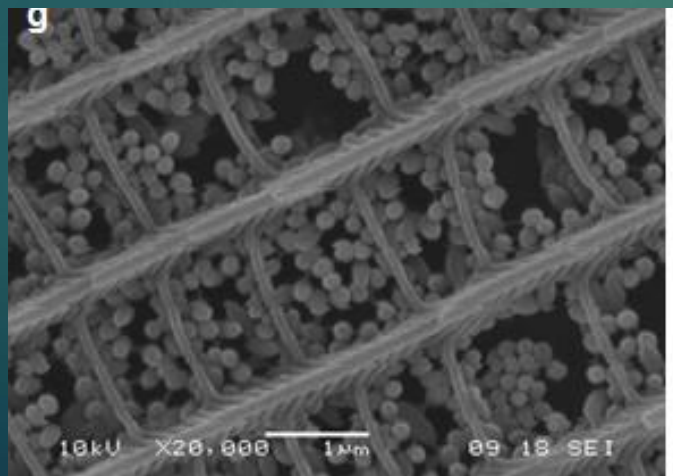


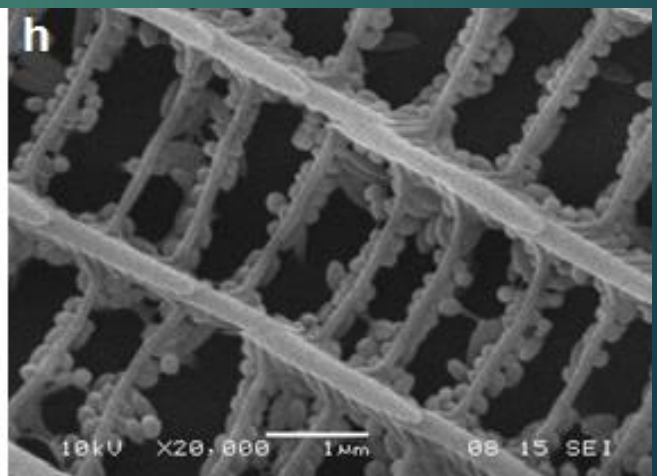




Biomimicry of Butterflies



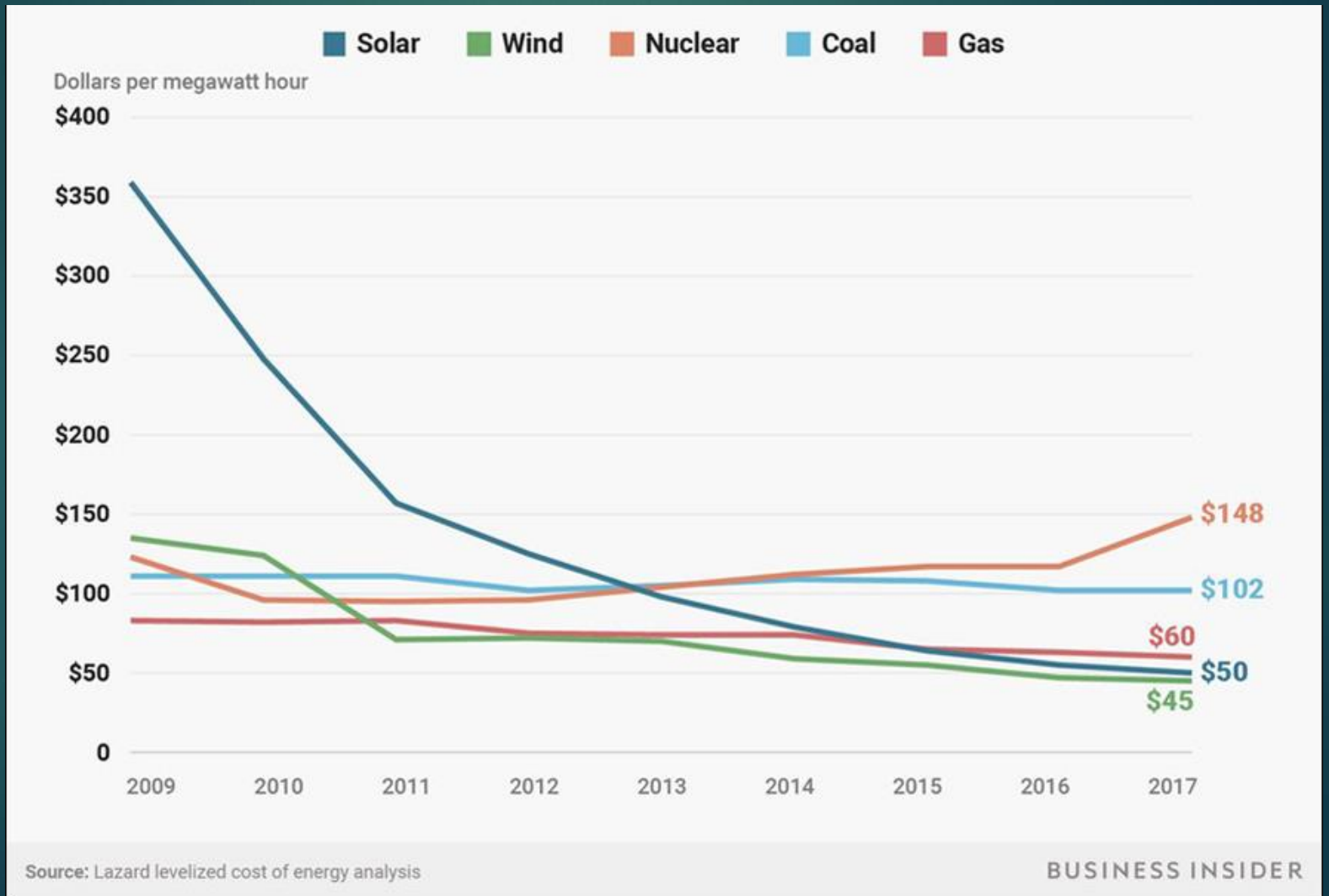




Art and Energy

- Infiltrating domestic market via art and aesthetic appeal.
- Trying to change the way the public think about solar panels and energy

But costs?
Silicon PV cost keeps falling



CPV vs. PV?

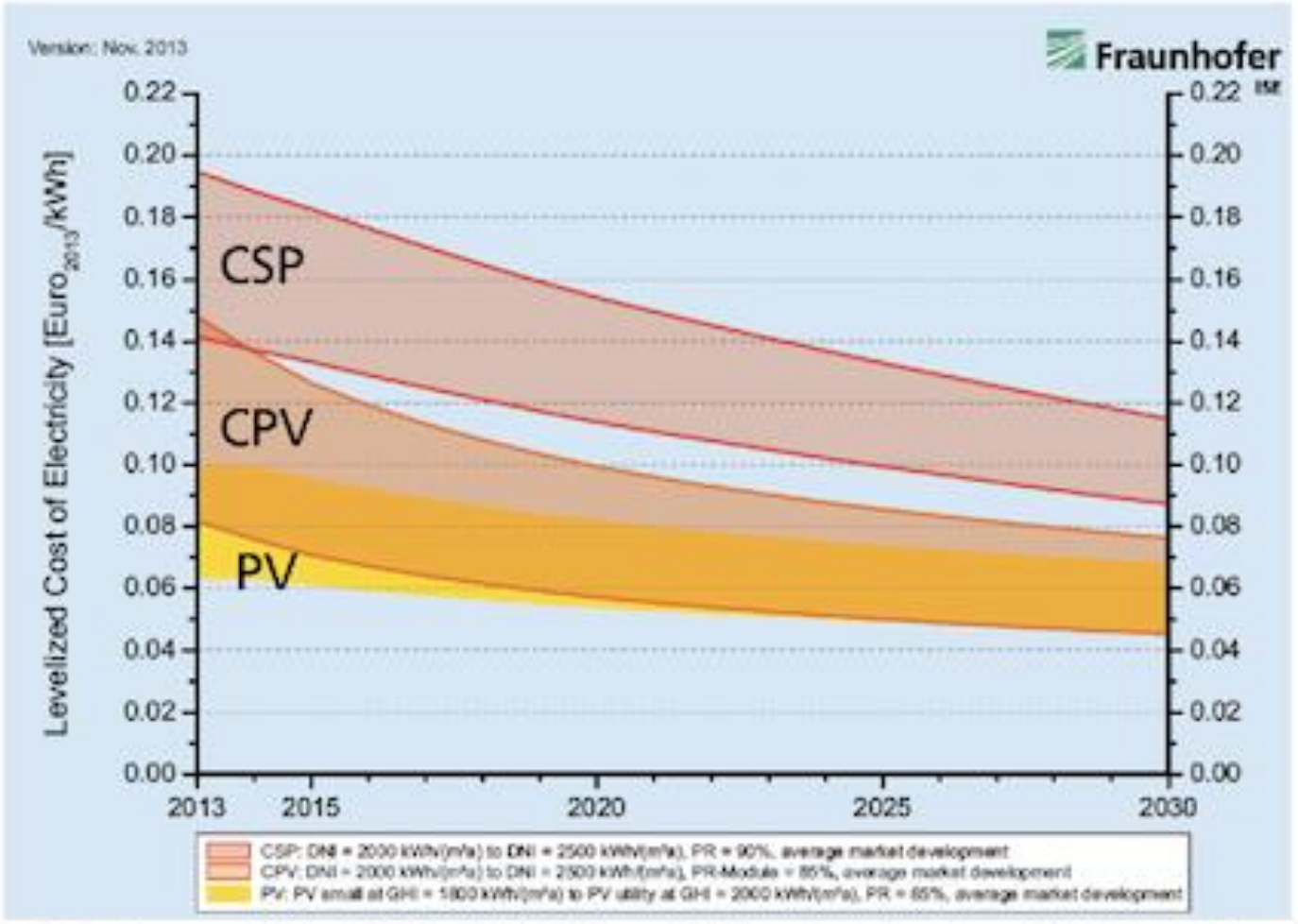
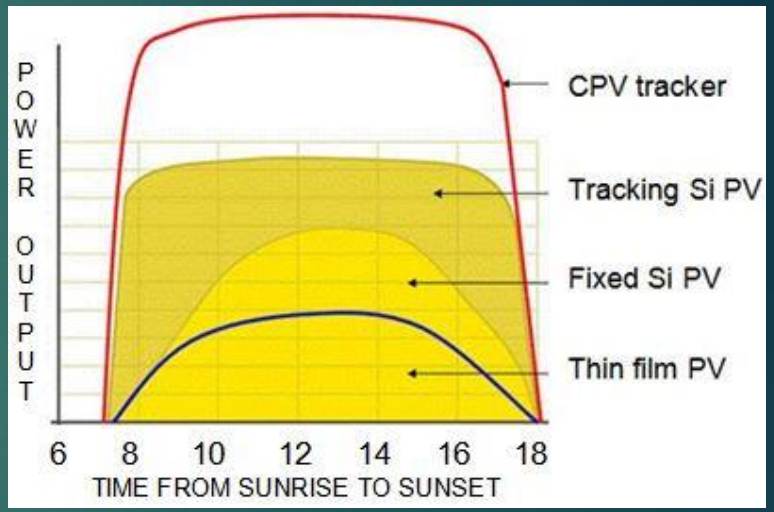
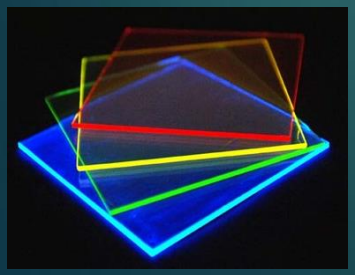


Figure 6: Development of the LCOE of PV, CSP and CPV plants at locations with high solar irradiation of 2000 kWh/(m²a) - 2500 kWh/(m²a). Source: [5].

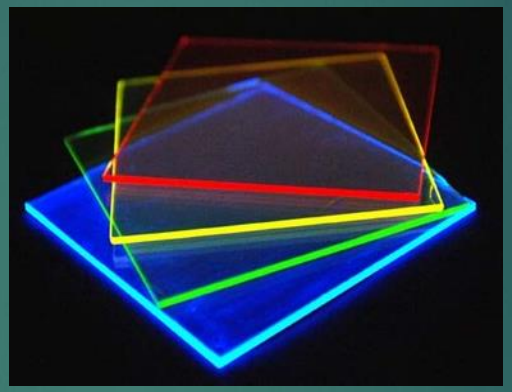
Energy and space efficient?

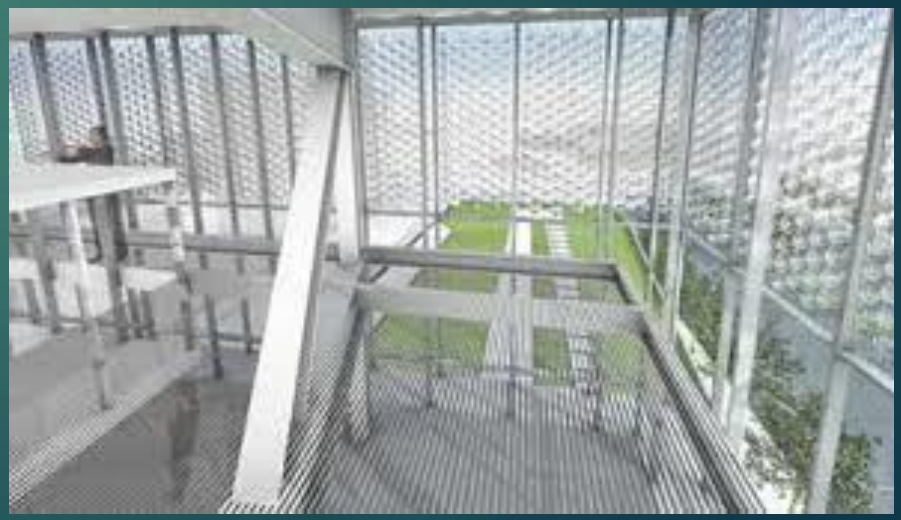
- Cells
  - p-Si ~ 375$/m^2
  - c-Si (concentration optimised) ~ 1000$/m^2
  - III-V ~ 35000-50000 $/m^2
- Shifting the system costs towards cheaper materials could reduce costs
- Higher efficiency, more power output for limited space applications.
- More eco friendly, less mining.
- Flexible in design and aesthetics.



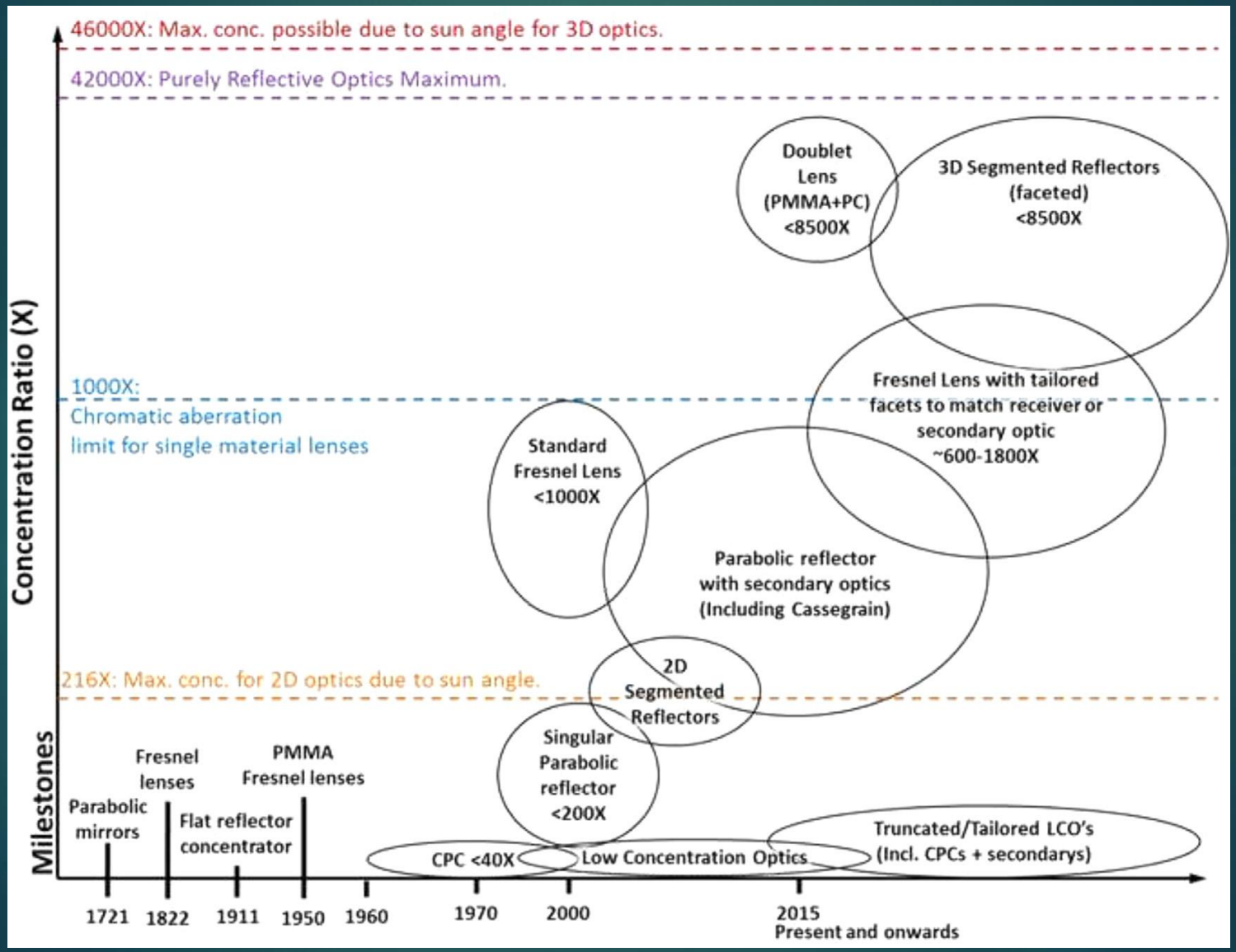


Building Aesthetics





CPV progress and summary

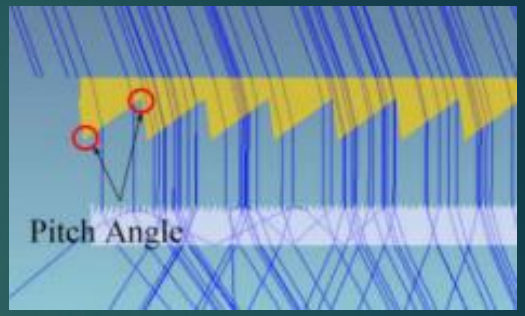


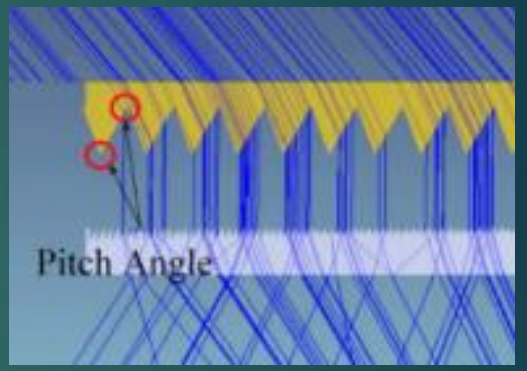
CPV progress and summary

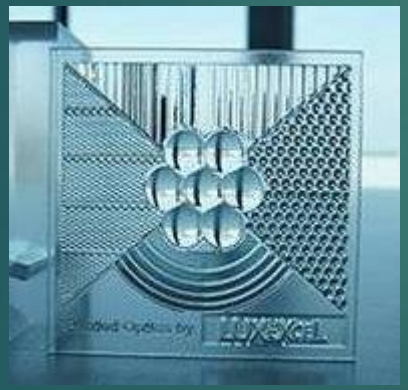
- Thin (similar to PV Panel), lightweight and practical
- Building integrated and other limited spaces
- Segmented optics
- New (or investigate old) materials and manufacturing
  - 3D printing
- MicroCPV
- Consideration of Application and Location

UNSW Research Collaboration

- Beam Steering optics for CPV and PV
  - 3D Printing Optics
    - Printing layers of refractive index
    - Post Shrinking prints to improve resolution



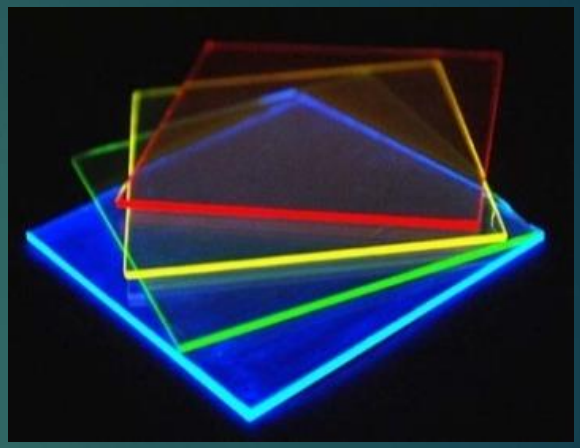


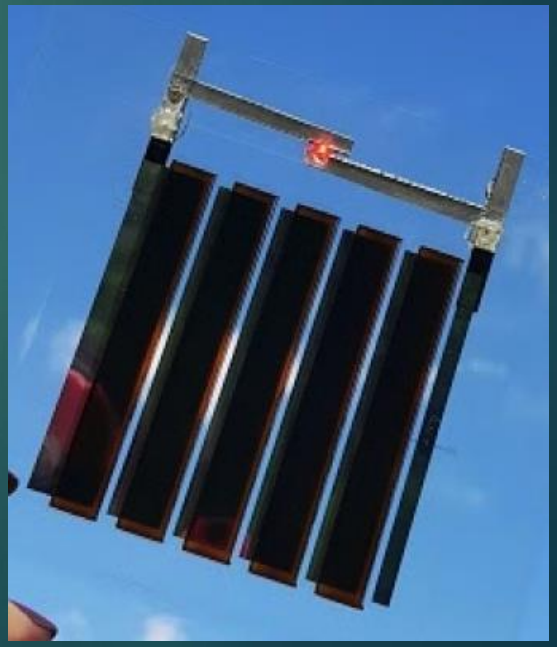


  - Perovskite efficiencies at increased concentration?
    - Not yet been done, high impact publication likely.

UNSW Research Collaboration

- Open to collaborations
- Perovskite +CPV?
  - Perovskites suffer from UV degradation
    - Downshifting luminescent concentrators
  - Perovskites suffer from exposure to the air/moisture in air
    - Sealed under other CPV optics.
  - Not yet been done, high impact publication likely.





Thank you for your time

- Questions?

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