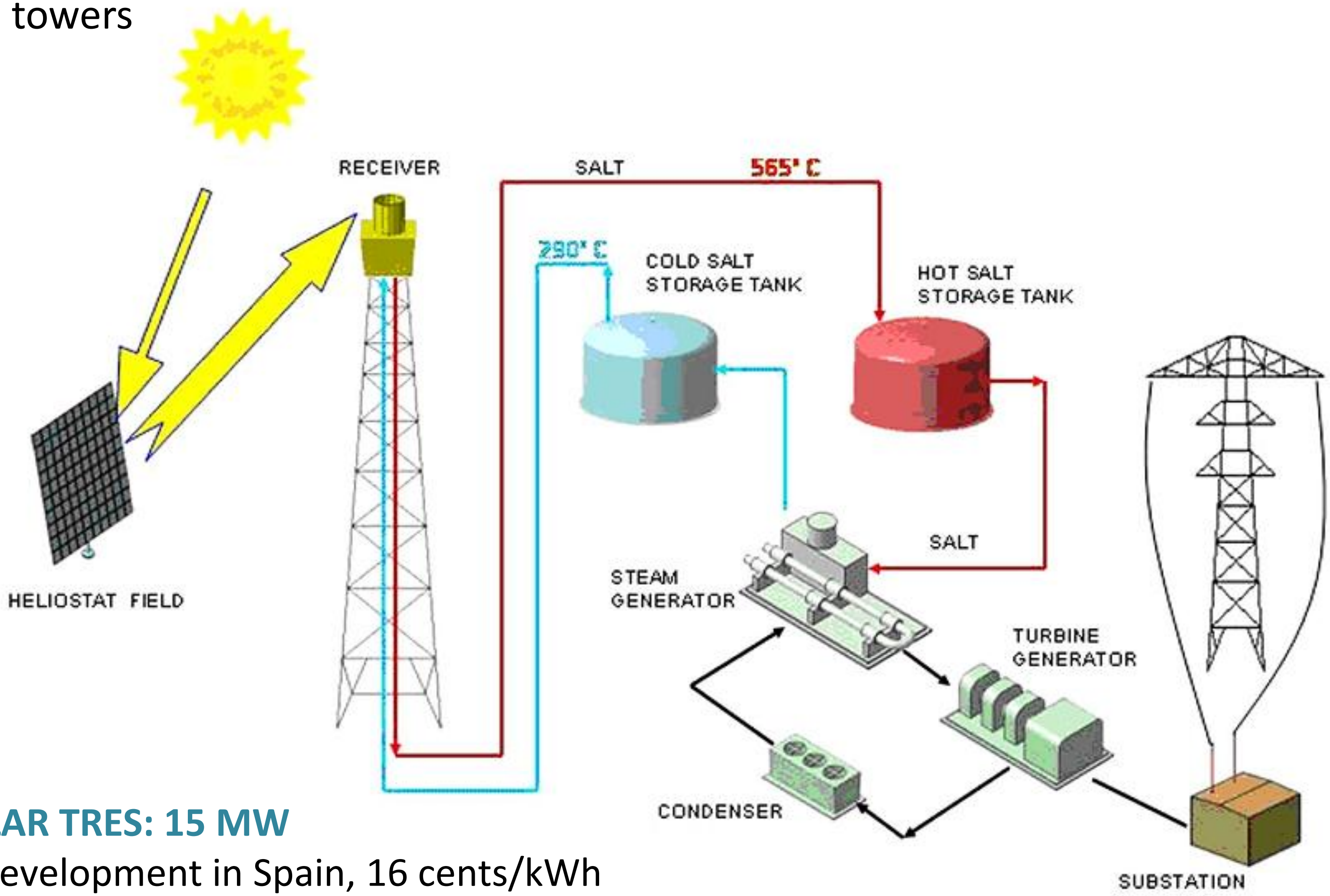
Materials Research: Central Receiver Power Plants

Kari Nigorizawa
MSE 395, Spring 2009
Professor Dunand

Central Receiver Systems (CRS)

Also known as central tower power plants, heliostat power plants, or solar power towers



SOLAR TRES: 15 MW

In development in Spain, 16 cents/kWh

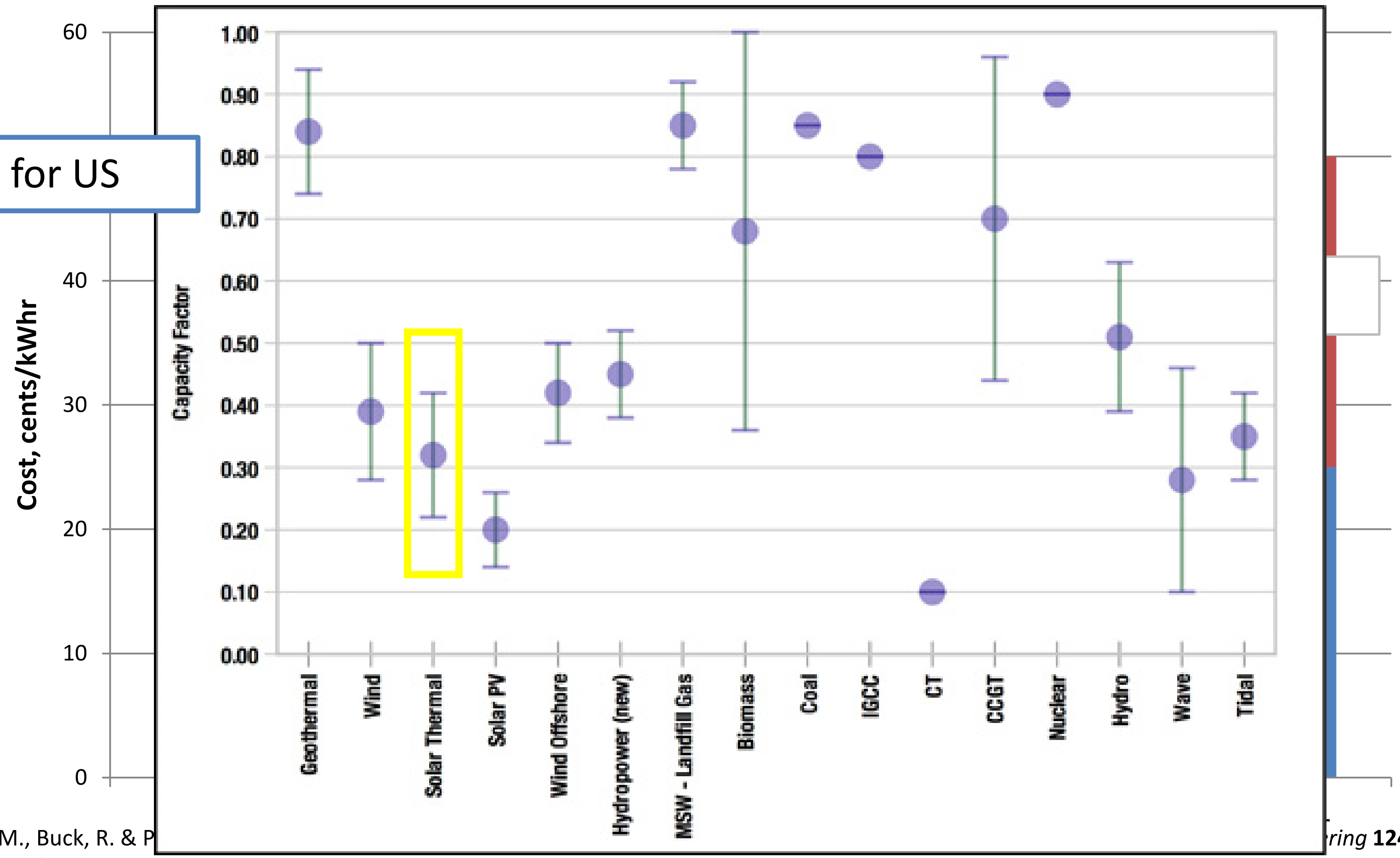
Ortega, J. Ignacio, J. Ignacio Burgaleta, and Felix M. Tellez. "Central Receiver System Solar Power Plant Using Molten Salt as Heat Transfer Fluid." Journal of Solar Energy Engineering. 130.2 (2008): 024501-6. <http://link.aip.org/link/?SLE/130/024501/1>.

Cost Comparison

It has been projected that future CRS's will produce energy at costs competitive with natural gas and/or oil.

Current designs produce energy at around 18 cents per kWhr

Capacity for US

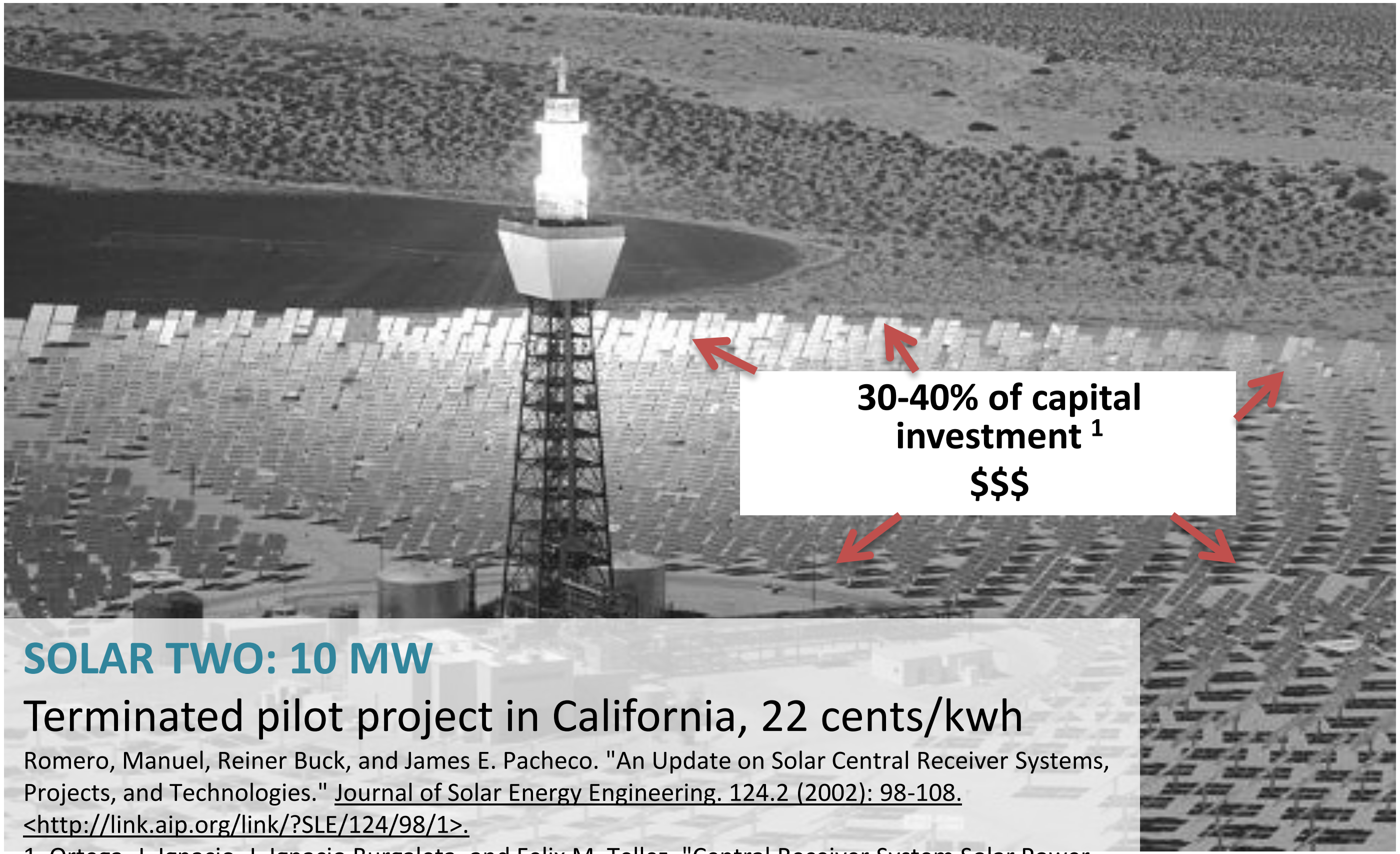


Romero, M., Buck, R. & P ... *ring* **124**, 98-108 (2002).

NREL.   (2002). http://www.nrel.gov/analysis/capfactor.html

Focus

This presentation focuses on materials selection & design of heliostats for CRS power plants. More specifically, the reflectant module components.



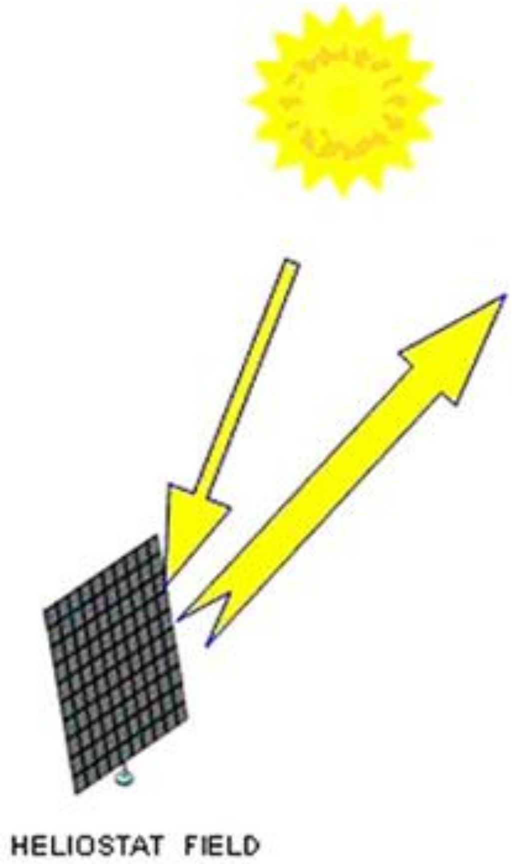
SOLAR TWO: 10 MW

Terminated pilot project in California, 22 cents/kwh

Romero, Manuel, Reiner Buck, and James E. Pacheco. "An Update on Solar Central Receiver Systems, Projects, and Technologies." Journal of Solar Energy Engineering. 124.2 (2002): 98-108. <http://link.aip.org/link/?SLE/124/98/1>.

1, Ortega, J. Ignacio, J. Ignacio Burgaleta, and Felix M. Tellez. "Central Receiver System Solar Power

Desired properties of reflectant module



- High reflectivity (DOE goal: >90%)

$$\rho = \frac{G_{refl}}{G_{incident}}$$

Average reflectivity

G=spectral intensity averaged over all wavelengths

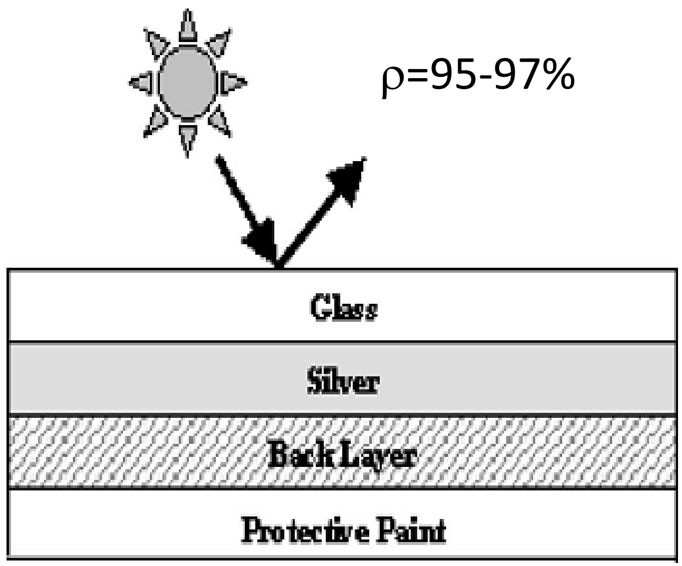
- Low cost (DOE goal: $1/ft^2)
- Durable in high temperature, outdoor environments (DOE goal: 10 year life)

Kennedy, C. E., and K. Terwilliger. "Optical Durability of Candidate Solar Reflectors." Journal of Solar Energy Engineering. 127.2 (2005): 262-69. <http://link.aip.org/link/?SLE/127/262/1
http://dx.doi.org/10.1115/1.1861926>.

Conventional reflector module: Thick glass/Silver

Developed by McDonnell Douglas in late 1970's

Currently \$4-6/ft^2 at high production volumes

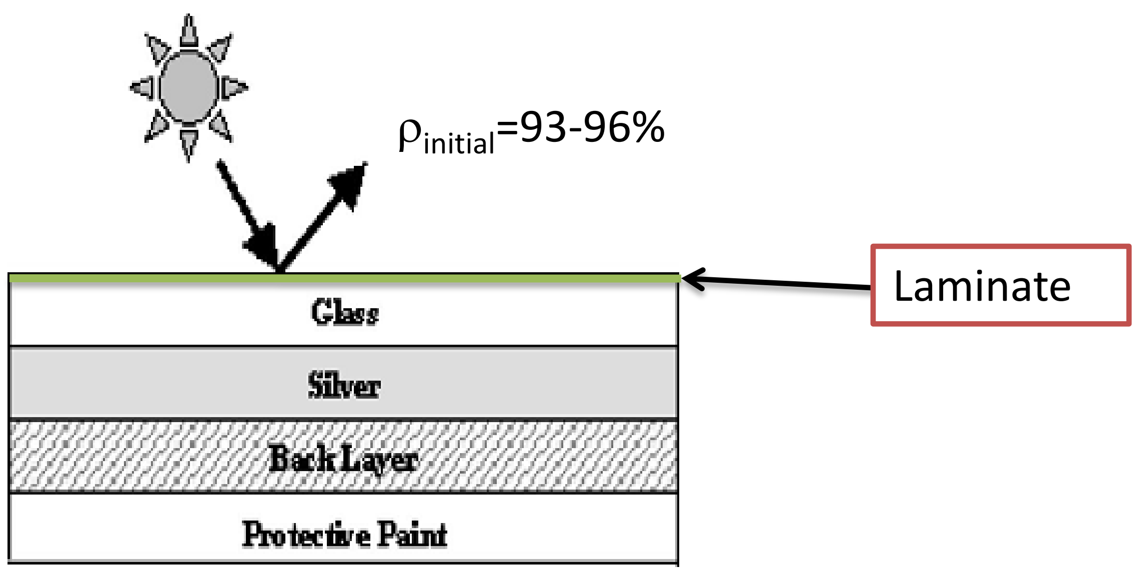


Drawbacks: heavy, cost could be reduced, and silver's absorption band

Kennedy, C. E. & Terwilliger, K. Optical Durability of Candidate Solar Reflectors. *Journal of Solar Energy Engineering* **127**, 262-269 (2005).

Reducing weight and costs: Thin glass/Silver

Currently \$1.5-4.0/ft^2 at high production volumes



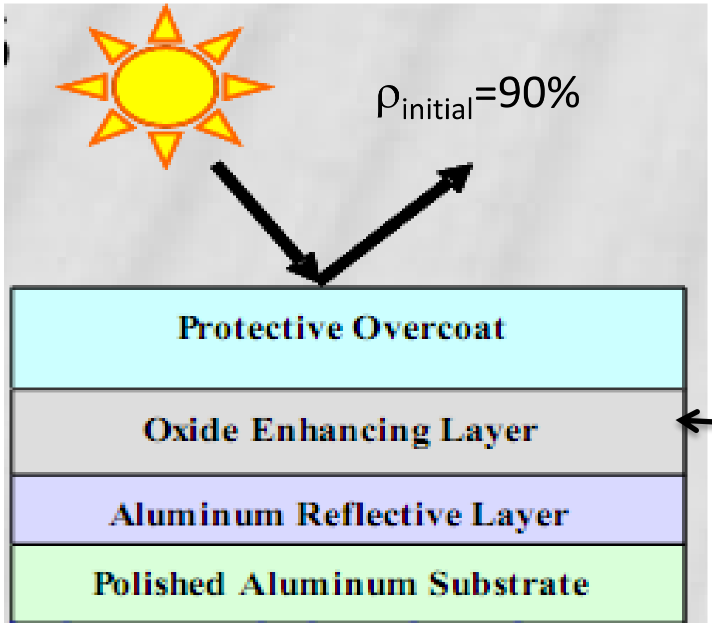
Drawbacks: fragile and difficult to handle, corrosion after 2 years where no adhesive, adhesive effects ρ over time

Kennedy, C. E. & Terwilliger, K. Optical Durability of Candidate Solar Reflectors. *Journal of Solar Energy Engineering* **127**, 262-269 (2005).

Reducing cost further: Aluminized reflectors with nanocomposite top layer

Currently \$2/ft^2 from Alonod

- Previous designs with single protective oxide topcoat not durable
- Previous designs with added polymer coat on top of oxide coat improved durability, but caused loss of reflectivity and delamination



Tuned to enhance solar reflectance (proprietary)

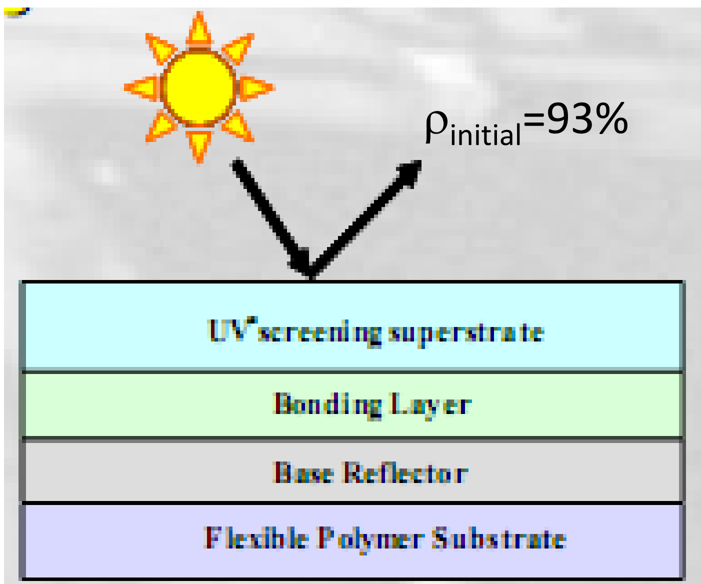
Drawbacks: more durability testing needed, low $\rho_{initial}$

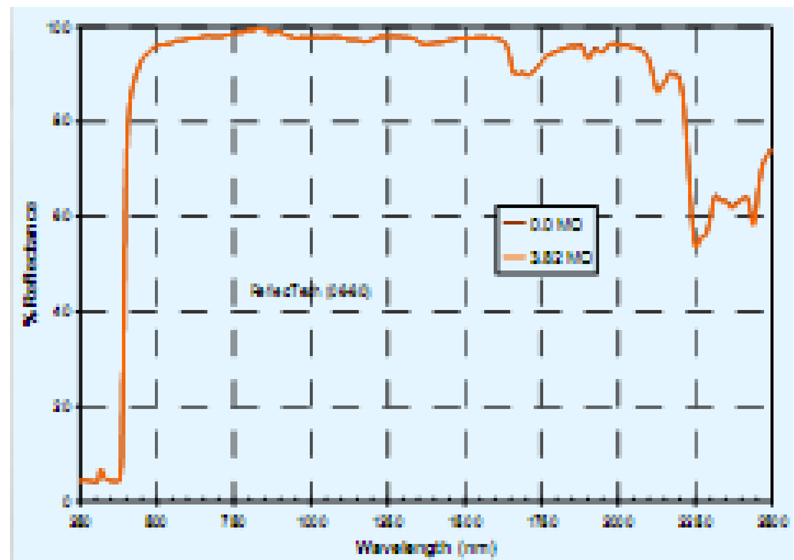
NREL. Optical Durability of Candidate Solar Reflector Materials. ed., 2007. <www.nrel.gov/docs/fy07osti/41428.pdf>.

Increased durability at low costs: Silvered Polymer Reflectors

Currently \$1.50/ft^2 from ReflecTech

- 3M developed first design, problem with delamination between polymer substrate (PMMA) and Ag
- Addition of UV screening layer added durability





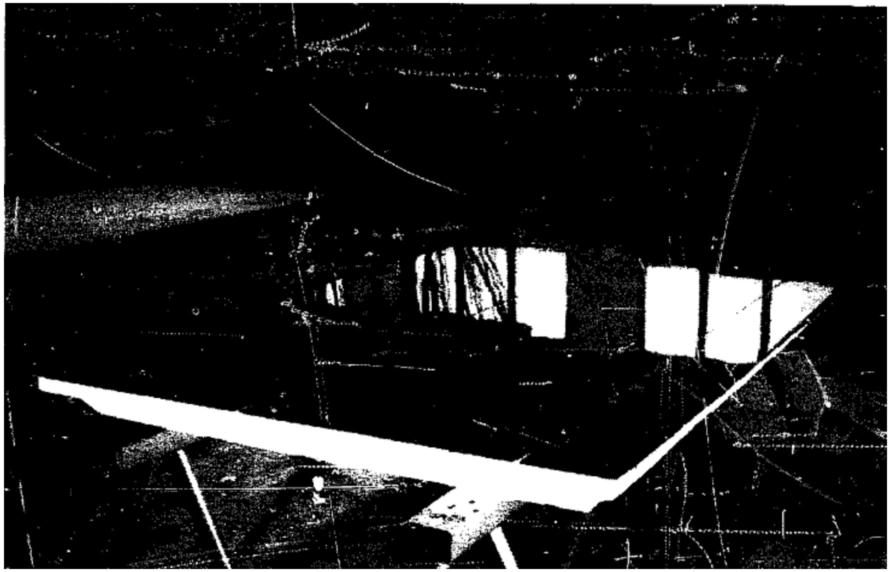
Drawbacks: losses in ρ during accelerated testing

NREL. Optical Durability of Candidate Solar Reflector Materials. ed., 2007. <www.nrel.gov/docs/fy07osti/41428.pdf>.

Glass fiber reinforced polyester sandwiches (GFRP)

Idea: replace glass mirrors and metallic frames with single lightweight composite

Advantages: weight reduction, single piece for support and reflector, provides stiff structure with 3-4 plies of upper laminate

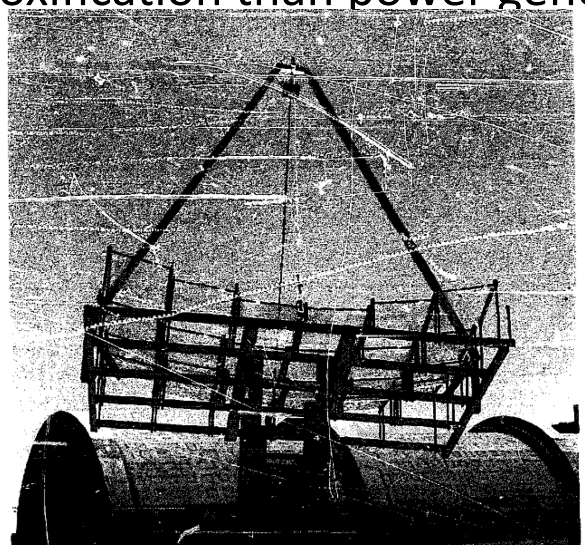


Drawbacks: still in development, problems with resin cure and focal length reduction

Romero, Manuel, Eduardo Conejero, and Marcelino Sanchez. "Recent Experiences on Reflectant Module Components for Innovative Heliostats." Solar Energy Materials. 24.1-4 (1991): 320-32. <http://www.sciencedirect.com/science/article/B7571-47YJBVT-1H/2/e996b867534df8d8050f59ac219f8f13>.

Current materials research, less developed in the literature

- Holographic concentrators that optimize reflectivity in the UV (more useful for water detoxification than power generation)



- Enhancing adhesion of UV transparent polymers and sol-gel coatings of metallic membranes→direct metallization of reflector surfaces

Summary

Material	Cost ($\$/ft^2$)	$\rho_{initial}$ (%)	Drawbacks
Thick glass/Ag	4-6	95-97	heavy, high cost, and silver's absorption band
Thin glass/Ag	1.5-4	93-96	fragile and difficult to handle, corrosion after 2 years where no adhesive, adhesive effects ρ over time
Aluminized reflectors	2	90	more durability testing needed, low $\rho_{initial}$
Silvered polymer reflectors	1.5	93	losses in ρ during accelerated testing, more testing needed
Glass fiber reinforced polyester sandwiches	?	?	still in development, problems with resin cure and focal length reduction