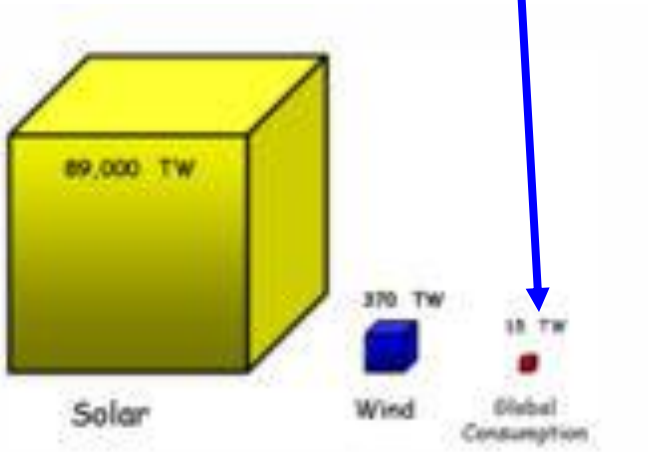
Solar Energy-An overview

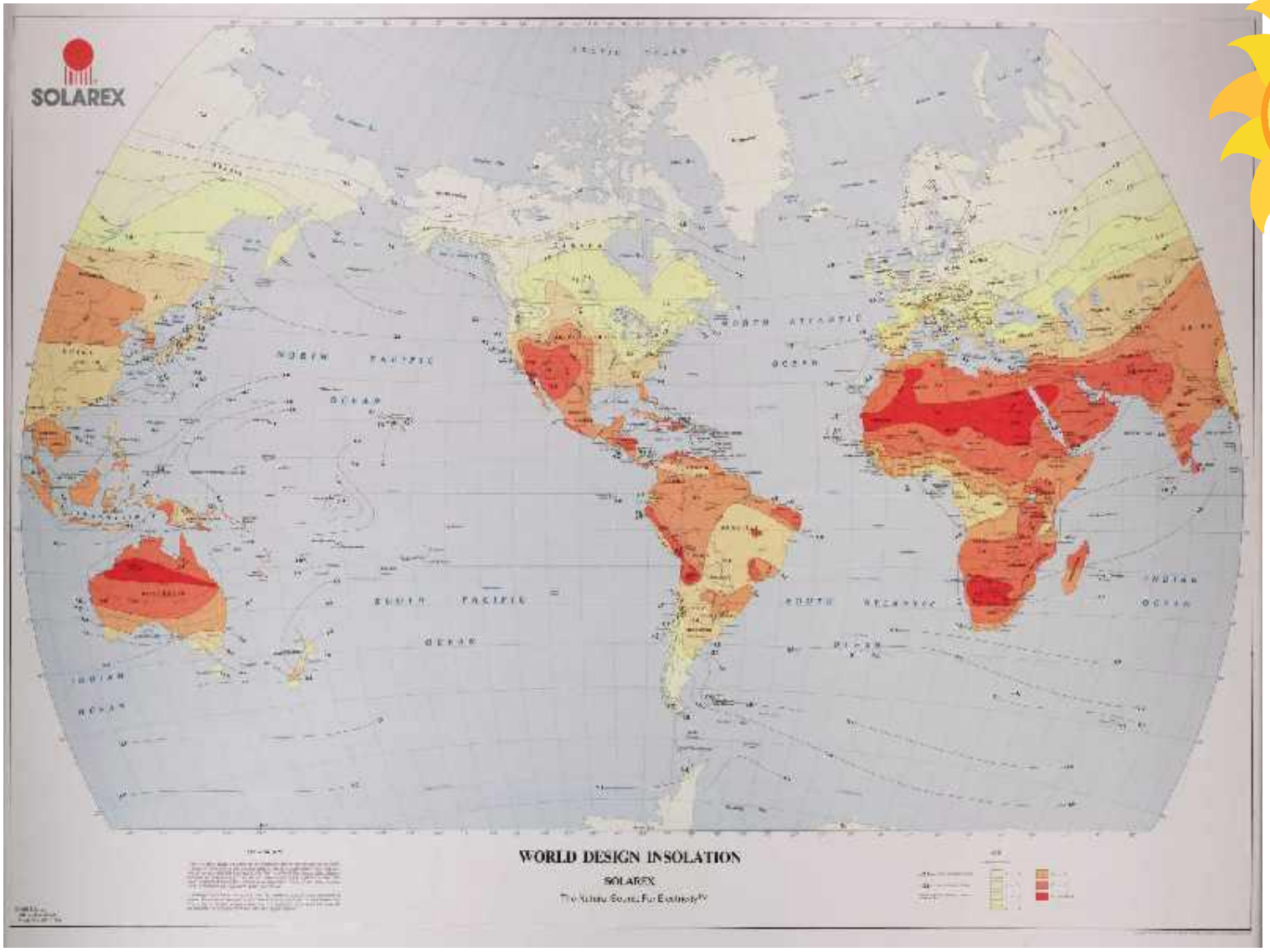
Solar is a GIANT source compared to what world uses

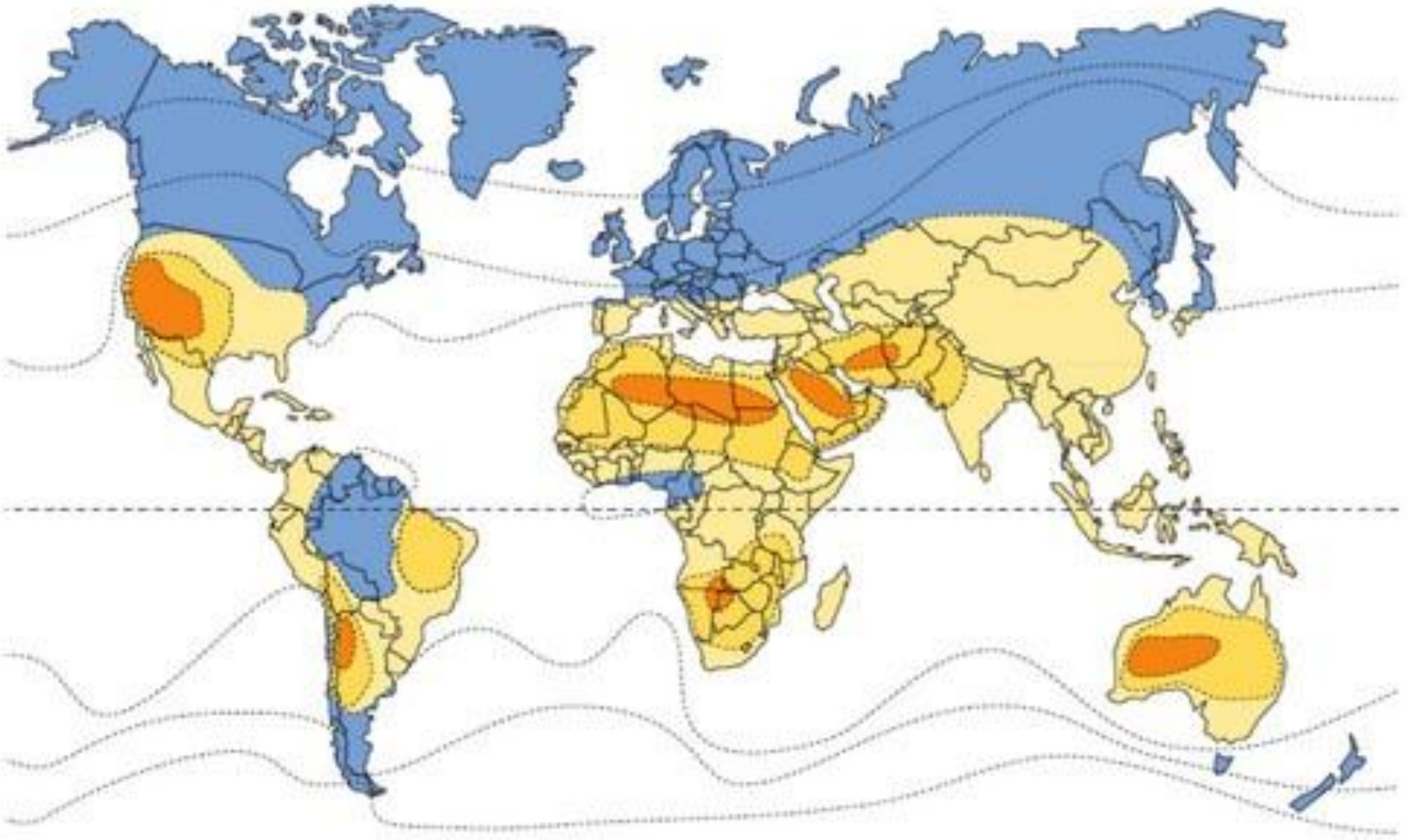
Potential
69k Terawatts

Use=16 TW



Solar energy atlas of the world




Suitability for solar thermal power plants:
Excellent
Good
Suitable
Unsuitable

Solar Heat: Archimedes burning Roman Fleet in Syracuse harbor: Why not power from heat?

Painting From Galleria Uffizi, Florence

Solar thermal

- Heat water
- Produce steam
- Drive a turbine
- Can get T~500 C-higher than nuclear plant
- So, Carnot efficiency for converting heat into electricity can be 52%
- Real~ 35+% (Comparable to nuclear plant-less than gas or coal plant)
- Large plants being built worldwide

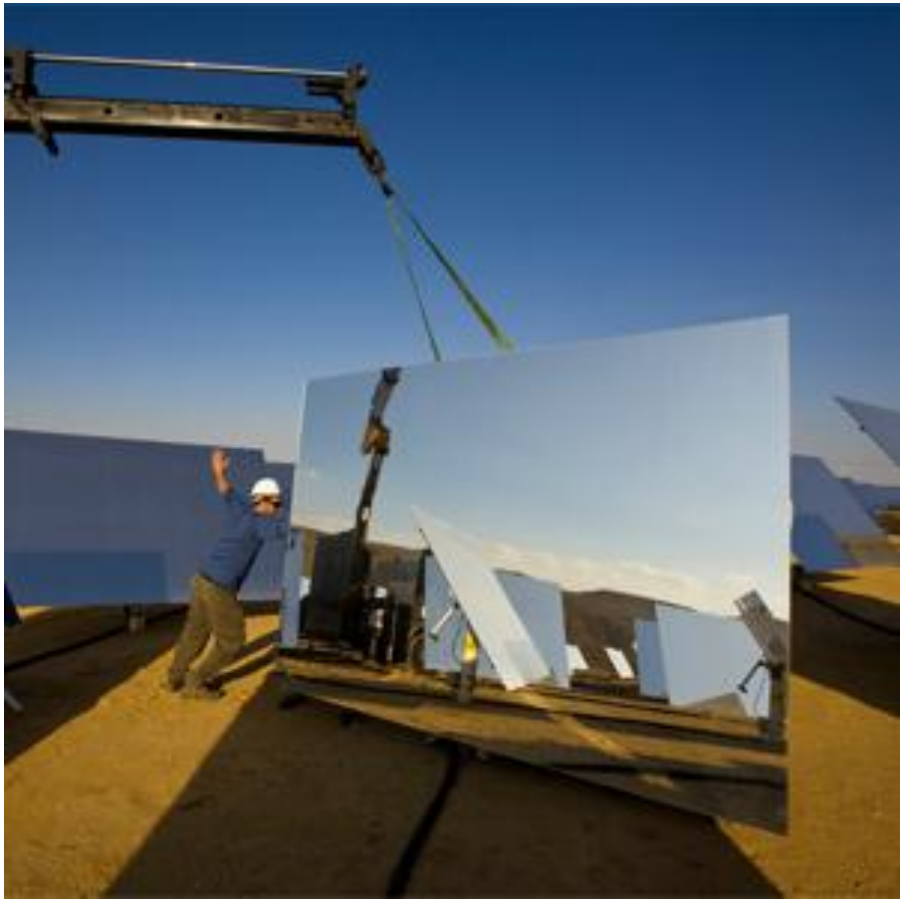
Solar Thermal-Electric – US leads – about 1GW under construction or operating

Ivanpah project-Mojave desert, CA

Photographs by Jamey Stillings

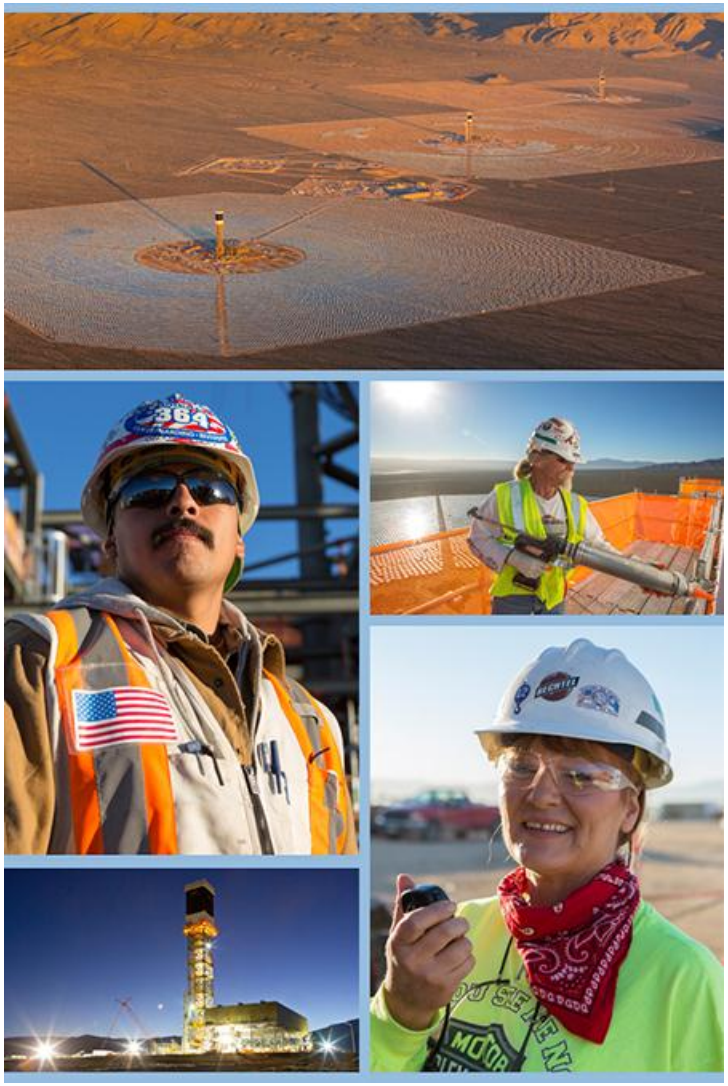
Out in the Mojave Desert in California, a power plant that could eventually generate enough **electricity for 140,000 homes** hopes to get its moment in the sun soon. When the **$2.2 billion solar thermal plant** known as Ivanpah is completed — sometime next year, if all goes according to plan — nearly **350,000 mirrors on 3,600 acres** will reflect light onto boilers. **Steam will power turbines, which will generate electricity that flows to California homes. It will be the largest such plant in the world.** These "solar workhorses of the desert," says V. John White, an analyst in Sacramento and an advocate for renewable energy, "can produce a lot of high-quality energy in the way that other renewable energies can't do. And there are only a handful of places on the planet that have solar radiation that good." But some opponents have criticized the Obama administration for pushing solar projects that don't pan out. The solar-panel maker Solyndra declared bankruptcy last year despite receiving $528 million in federally guaranteed loans, while BrightSource Energy, one of Ivanpah's developers, has benefited from a similar $1.6 billion government loan. It's expensive harnessing the sun. And the costs go beyond construction. BrightSource says that it has spent more than $56 million relocating desert tortoises.

A heliostat (tracking mirror) used for Ivanpah project



A field of mirrors- 100,000 installed as of date at Ivanpah

Central tower and some of the 2100 workers

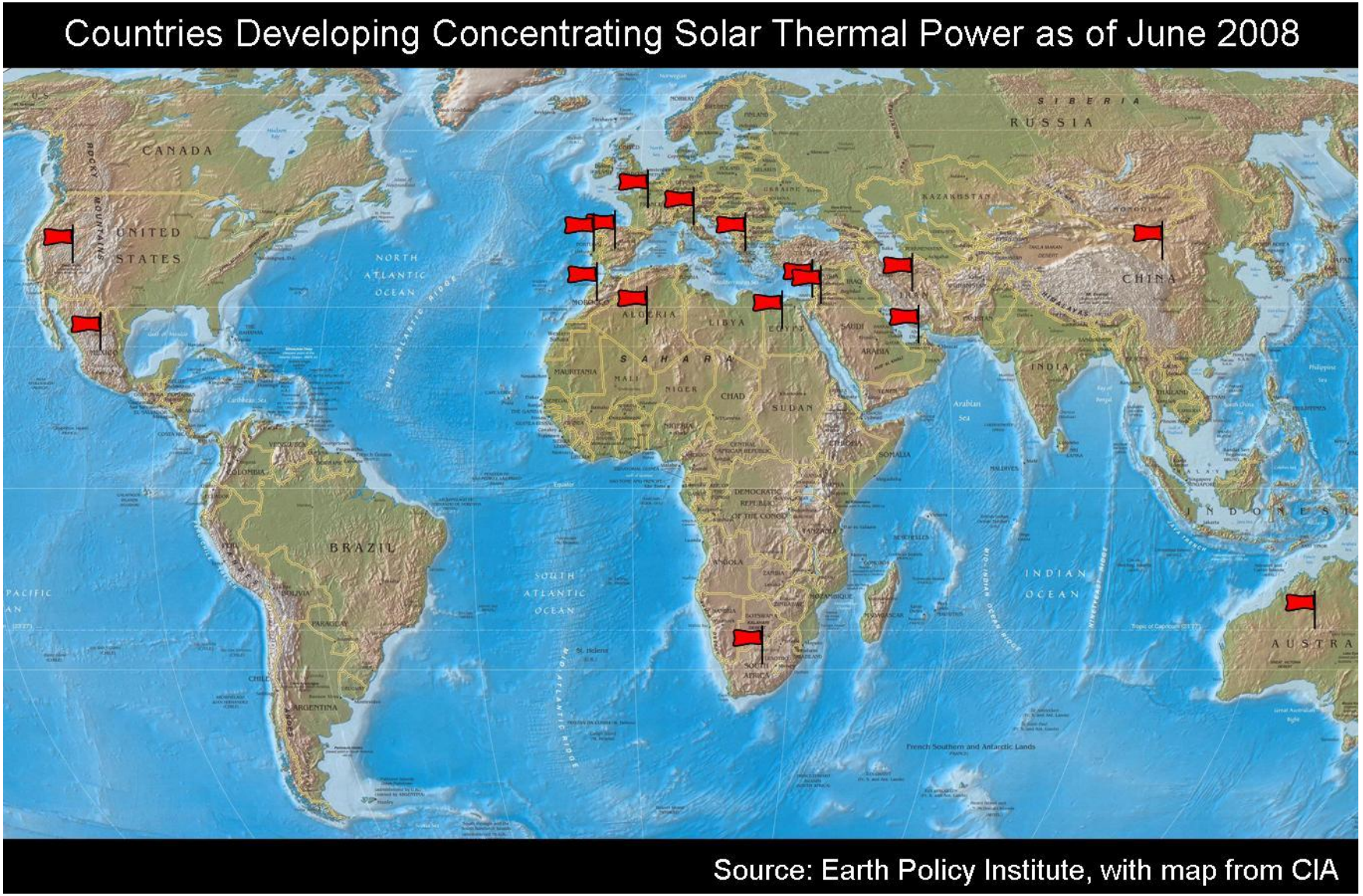


Parabolic trough generating steam-60 MW Operating Plant, Nevada

Nevada Solar One Plant-inside of parabolic reflector being constructed

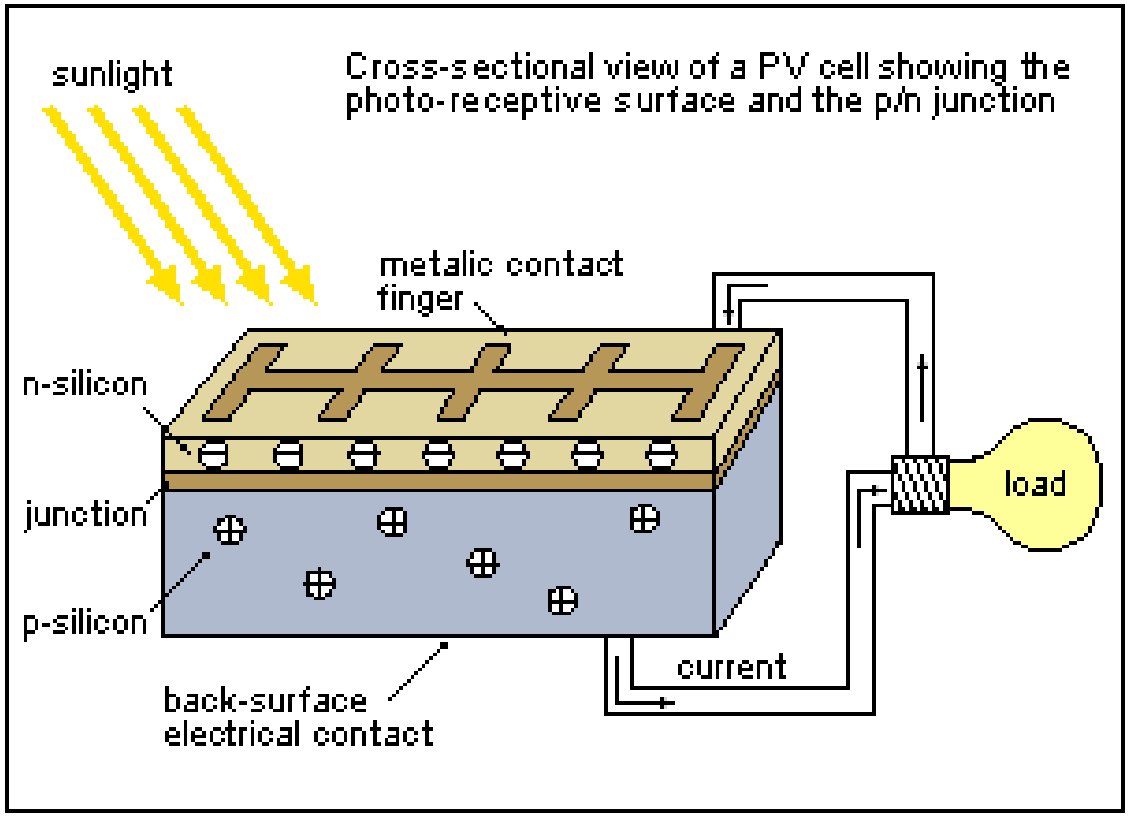
Tubing to Carry steam

Mirrors will be mounted on the truss



Europe planning to set up large plants in North Africa, transmit power through Strait of Gibraltar

Schematic diagram of a solar cell



A man in Malawi holding solar panel

Gujarat leads~700 MW: – Narmada Canal-top solar PV

Brilliant idea -save water evaporation and cool the solar cells-produce more output!

Charanka power plant-Gujarat, India
World's largest PV plant (600 MW)

Solar lanterns

Half the people in the world do not have electricity! Only 2% in some countries in Africa do!

India

Kenya

Is there a better investment than educating a child?

Cost of solar vs. kerosene lamp in Africa

Kerosene: ~$100/year for lighting!

Solar: $30 per lantern-5 year life!-4 hour battery charge/day

Billion lives campaign wants to give away 1 billion solar lamps to rural poor in India

Solar irrigation: Pure Water

The Naïade solar-powered water purifier that Electron Solar has just begun distributing as part of its solar-power range. The system uses mechanical cloth filters and a UV reactor to produce safe drinking water for rural populations.

600,000 children die from dysentery every year in the World ~One every minute!
PV irrigation and UV purification can prevent these

Solar refrigeration for rural areas: vaccines, anti-venom kits, antibiotics

Worldwide~125,000 deaths per year from snakebite
(Only 10 in the US)

Solar for developing world

- **Solar Energy for developing countries is not merely an energy source:**

  It is a life-changing, transformative technology, leading to economic development and better quality of life

Thin Film for Building Integration

Revolutionary Package of Proprietary Semiconductor Technologies

IOWA THIN FILM TECHNOLOGIES

Roll-To-Roll Manufacturing

Roll-to-roll manufacturing significantly reduces manufacturing costs. Our company was the first and remains the only company in the world that manufactures and sells monolithically-integrated solar panels on plastic using a true roll-to-roll manufacturing process.

Polymer Substrate

Flexible yet durable polyimide substrate results in enhanced flexibility, paper thinness, and lighter weight. The substrate is as thin as 1 mil (0.025mm) thick.

Thin Film Amorphous Silicon

Amorphous silicon is the absorber layer in the solar panels. The amount of silicon used in PowerFilm solar panels is as low as 1% of the amount used in traditional solar panels. PowerFilm has a strong environmental profile and is cadmium free. Single and tandem junction devices are manufactured. Finished panels are encapsulated in materials appropriate for the application environment.

13 Inches Wide
Up to 2400 Feet Long

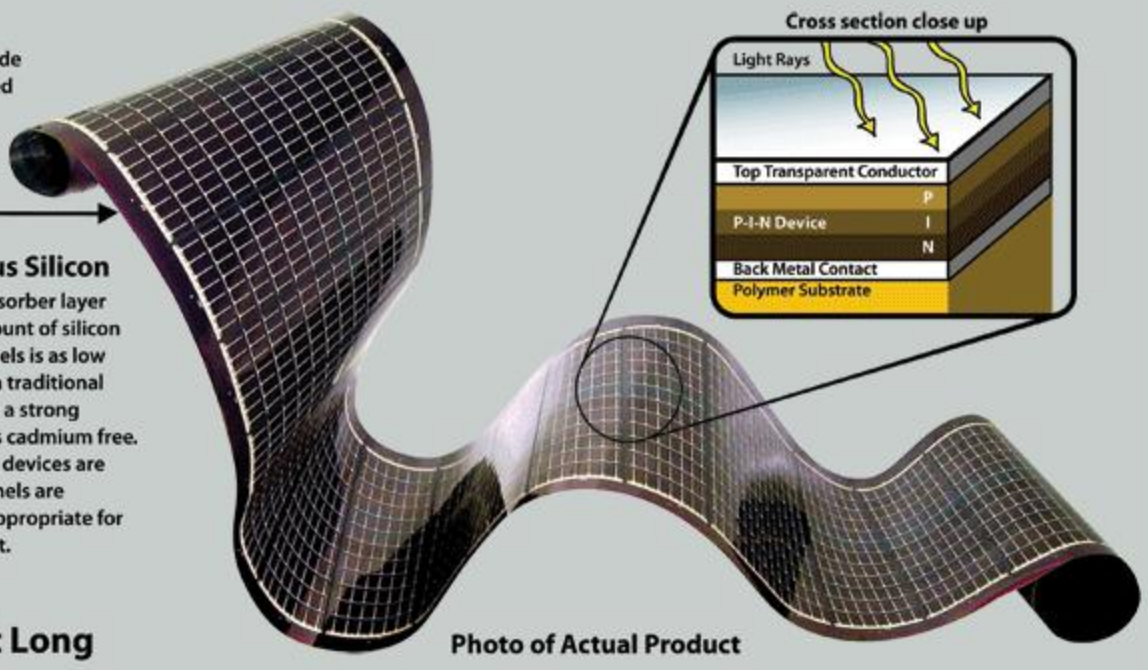


Photo of Actual Product

Monolithic Integration

Monolithic integration is the automatic built-in connection of individual solar cells. Monolithic integration reduces manufacturing costs (eliminates expensive labor for manual connection) and increases durability (eliminates stress-prone manual connections of individual solar cells).

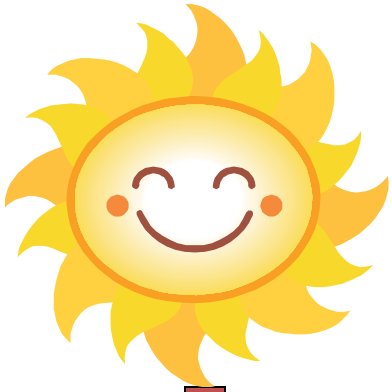
Product and Building Integration Technology

PowerFilm Solar also has developed low-cost technology to integrate the solar panels with fabric and metal for products and building materials.

Building integrated PV with plug-in hybrid car-built in storage

PV System Costs

Efficiency of conversion Important for central Power: reduce Area cost/kW



Area Dependent $40-90/m^2

Electronics Independent Of area

+ +

Σ **Cost**

PV module Cost-area dependent

Structure cost Field wiring cost

Dc- AC conversion cost

Today's cost of PV generation

- $4000/kW system
- 2000 kWh/kW per year
- **14 c/kWh-but only during daytime**
- PG&E charges anywhere from 12 c/kWh to 44 c/kWh for electricity depending on when and how much you use –CA average 14.8 c/kWh

PV is almost there!

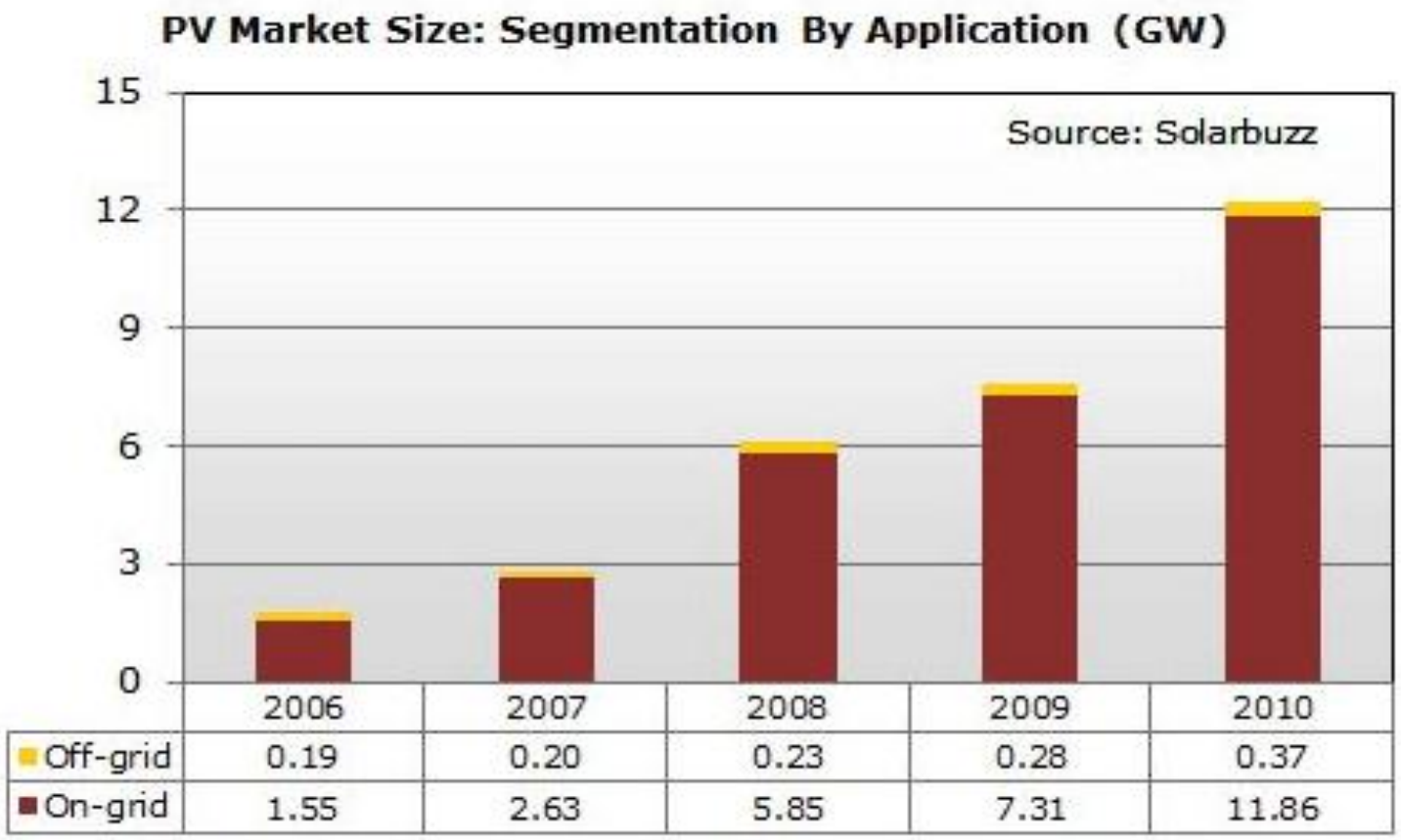
Today's cost of coal and natural gas plant generation

- Coal: Total cost: 8.2 c/kWh @ $60/t coal cost
- With $50/ton Carbon tax: 10.4 c/kWh
- Natural Gas: 11.7 c/kWh @ $7/MMBTU
- With C tax: 14 c/kWh

Solar PV

- Photovoltaic technology is growing rapidly
- In 2011, about 20 GW of modules were produced, about $40 billion in sales.
- Output Grew at 100+% in 2011.
- That is ~ 20 nuclear plants
- Zero nukes built in the US
- Costs are dropping rapidly
- What is the future?
- Si is the KING-will it always be?
- Which new materials, which technologies?
- Challenges for grid integration

2010- market segment – Grid dominated

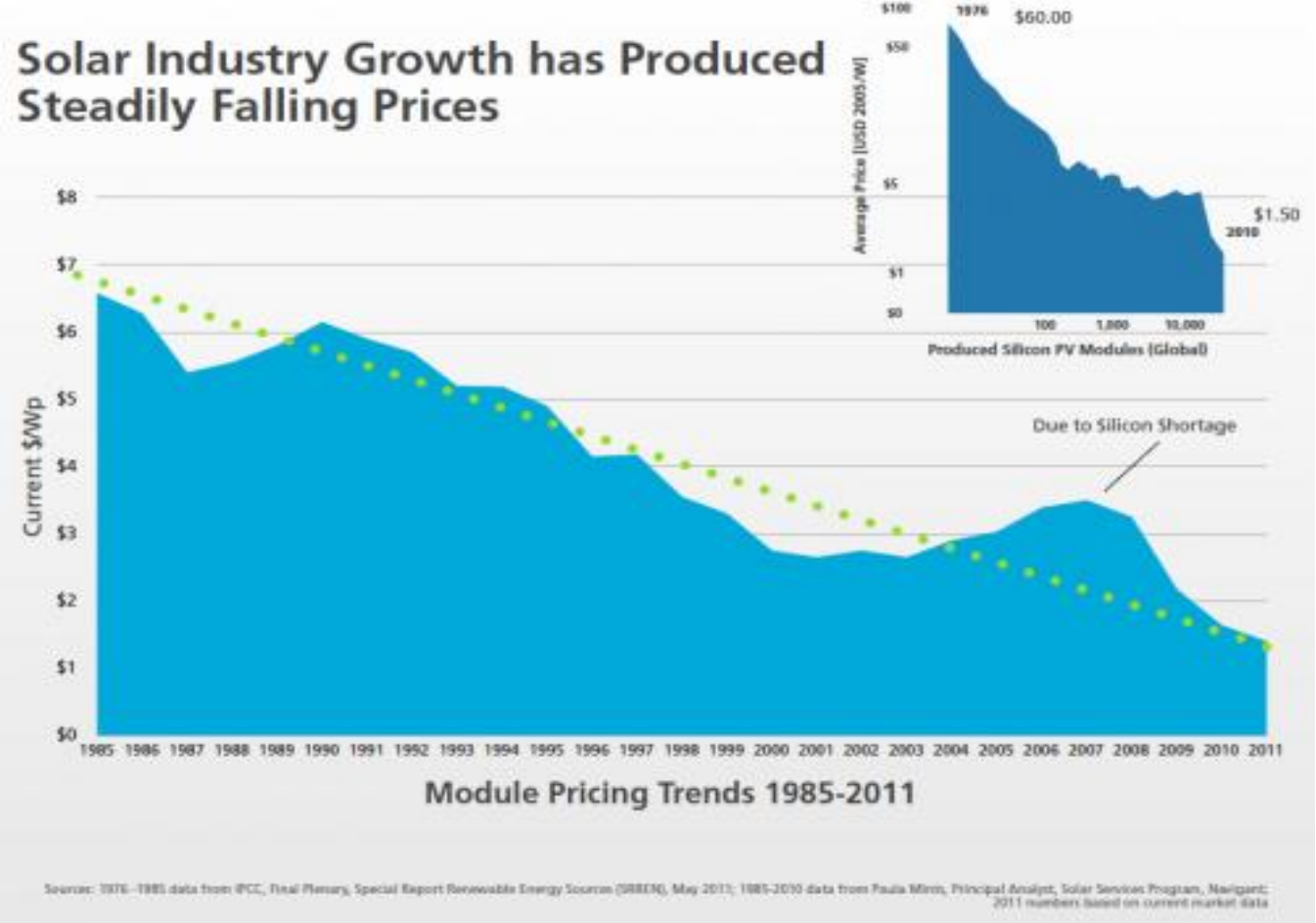


	2006	2007	2008	2009	2010
Off-grid	0.19	0.20	0.23	0.28	0.37
On-grid	1.55	2.63	5.85	7.31	11.86

Segmentation By technology

New Production Forecast (Jan-09)		2007	2008	2009	2010
Crystalline Si	Production (MWp)	2,520	3,630	5,633	9,131
CdTe	Production (MWp)	208	420	975	1,590
Amorphous Si	Production (MWp)	144	323	688	1,252
CIGS	Production (MWp)	9	34	94	240
Total	Production (MWp)	**2,881**	**4,407**	**7,390**	**12,213**
y/y growth			*53%*	*67%*	*65%*

Falling costs



Costs in 2011 : About $1.50/W- Reason: China- selling below cost

- All companies at a loss – but Chinese government subsidizes production

But-issue of storage

- Not a problem with solar thermal-can store heat easily in molten salts:
- How?

Heat storage

- Latent heat storage
- Primary steam melts salt
- Secondary loop regains heat from salt by freezing it and runs turbine

But-what kind of storage for PV?

Some Answers

- Flywheels
- Compressed air storage
- Pumped storage
- Batteries
- Chemical storage –split water with solar electricity, store H2-run engines or fuel cells with hydrogen

Do not want to run engines again

- Why not?

Carnot cycle loss again!
Why waste a good source of kinetic energy-electricity

Question of storage

- PV needs storage – wind even more so
- Power can go out in 1 minute if a cloud comes over
- If PV is >10% of the grid – major problem for the grid – grid stability, frequency control, voltage control
- What kinds of storage?

Central storage/back-up

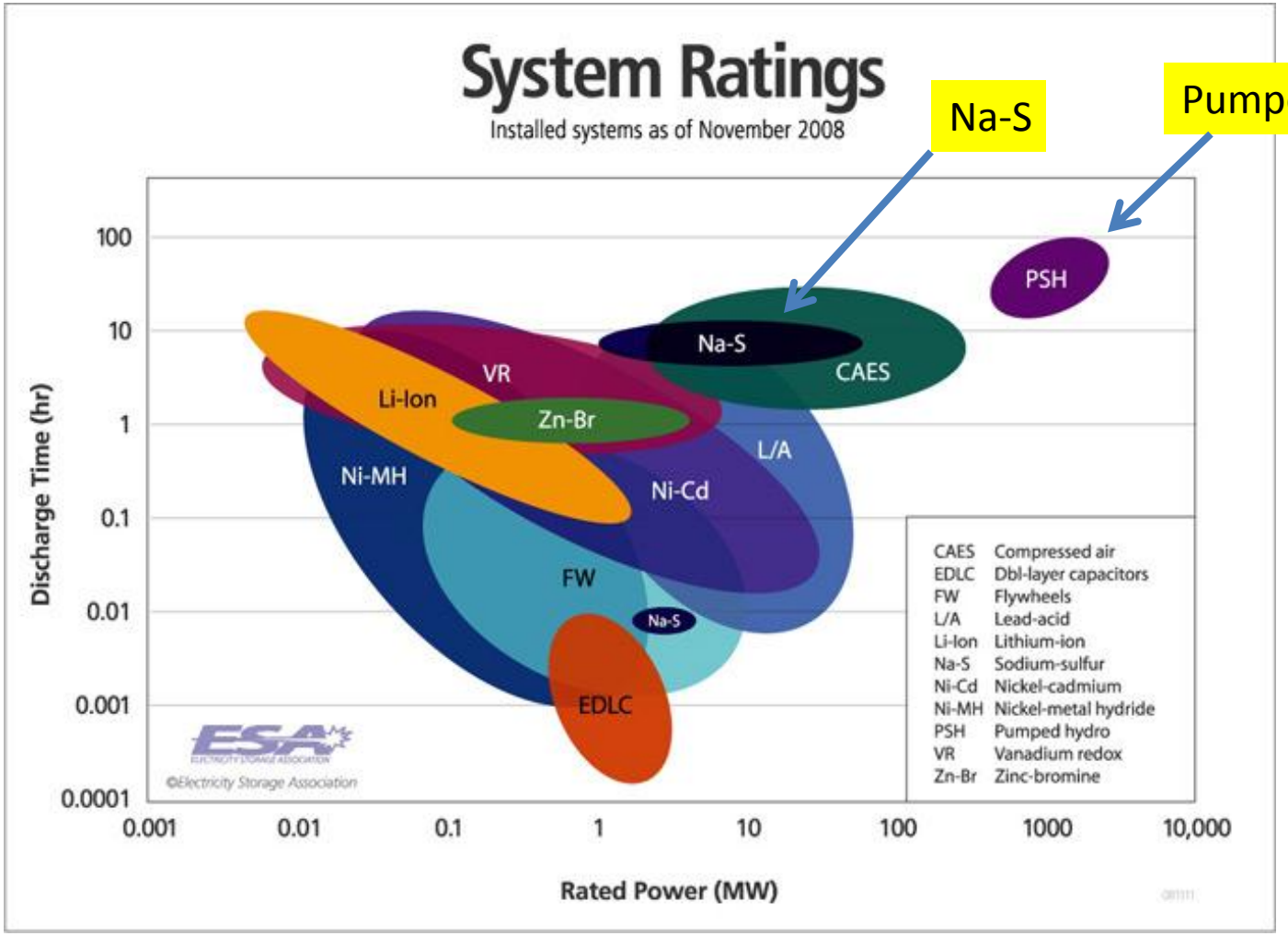
- Gas turbines – electric utilities are installing gas turbines as back up for wind – low capital cost- but needs inexpensive gas supply- great for U.S.
- Pumped storage – 65-70% efficient- but limited potential in both U.S. and India
- Hydro plants – use solar when sun is shining, hydro at night
- Compressed air energy storage-limited by geology

Localized storage

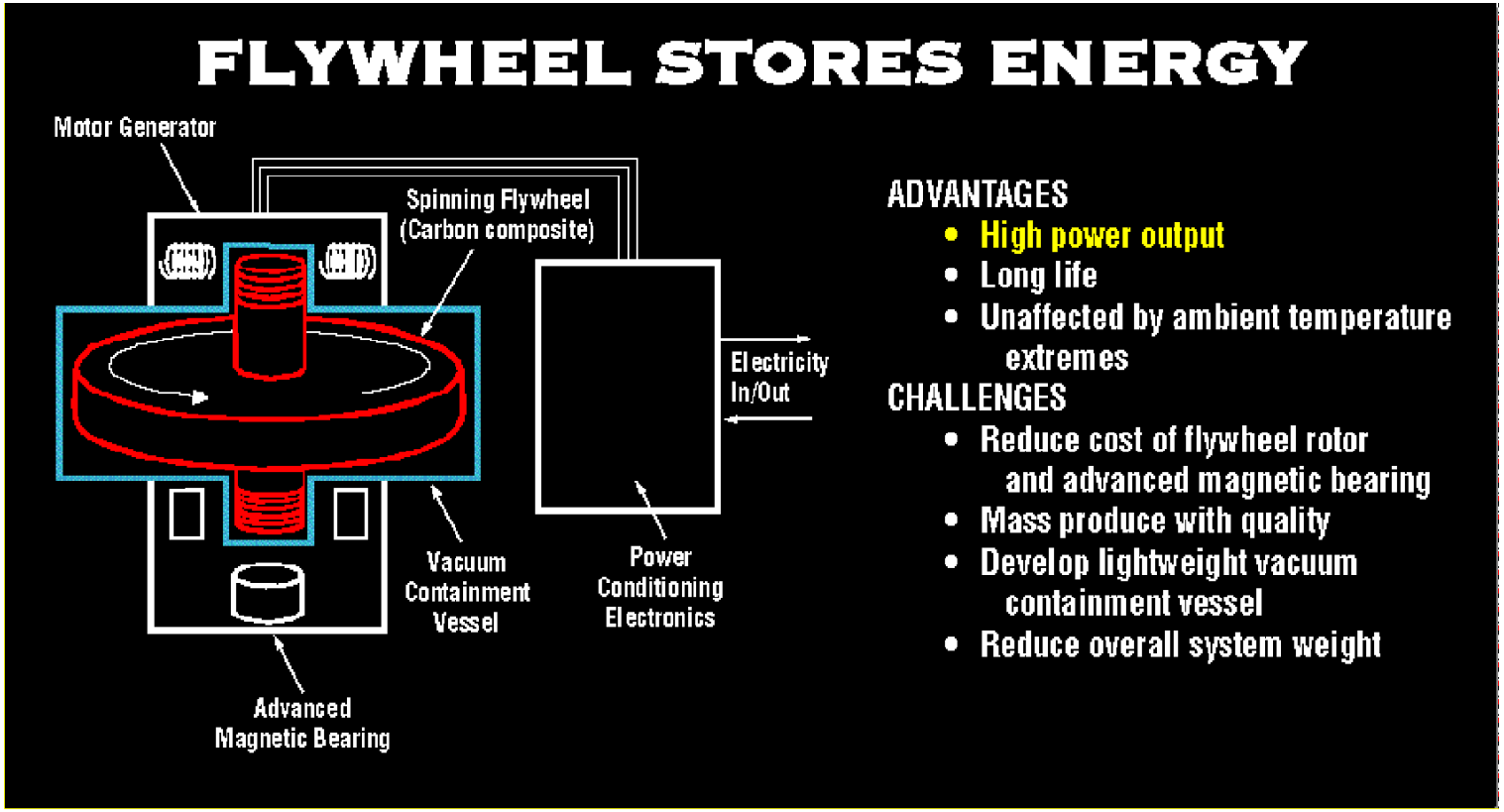
- Batteries – either a “community” battery park- a few hundred or few thousand kWh or
- Or localized, point of use storage
- Not Li-ion – too expensive
- Na-S battery will work very well -but only in “commu[illegible]ark- not suited for homes
- Lead aci[illegible]

Na-S battery bank in Nagoya, Japan

Advantages of Na-S battery- perfect for small-medium applications



Flywheels- carbon fiber – Good for short duration energy storage – for utility grid stability control



Williams Flywheel (U.K.)

Conclusions for now

- All solar technologies are competitive
- Different applications-different solutions
- Economics depend on application
- Storage going to be important
- Small scale and large scale storage
- Transient and longer term storage
- We will discuss the physics of all of these