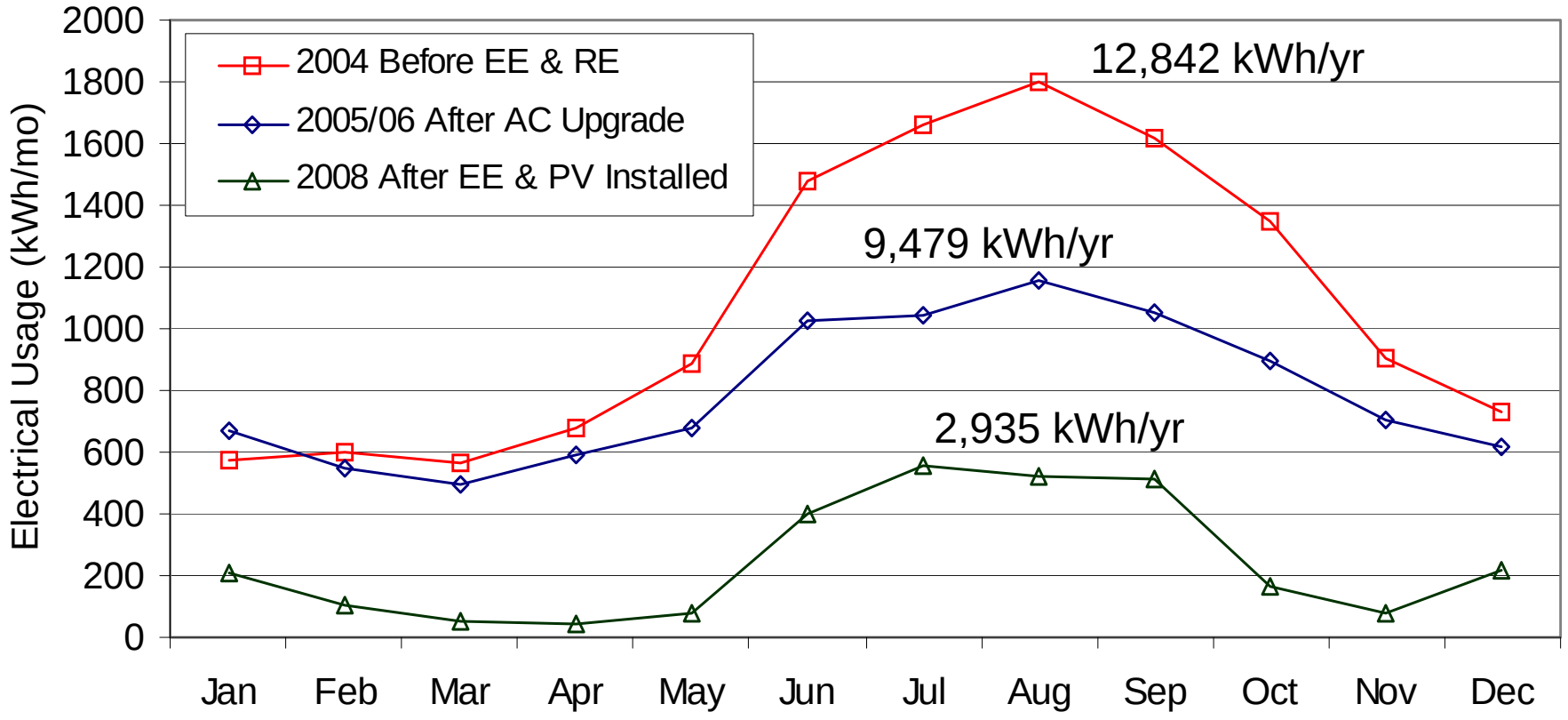
Bringing Solar PV Mainstream

AIChE

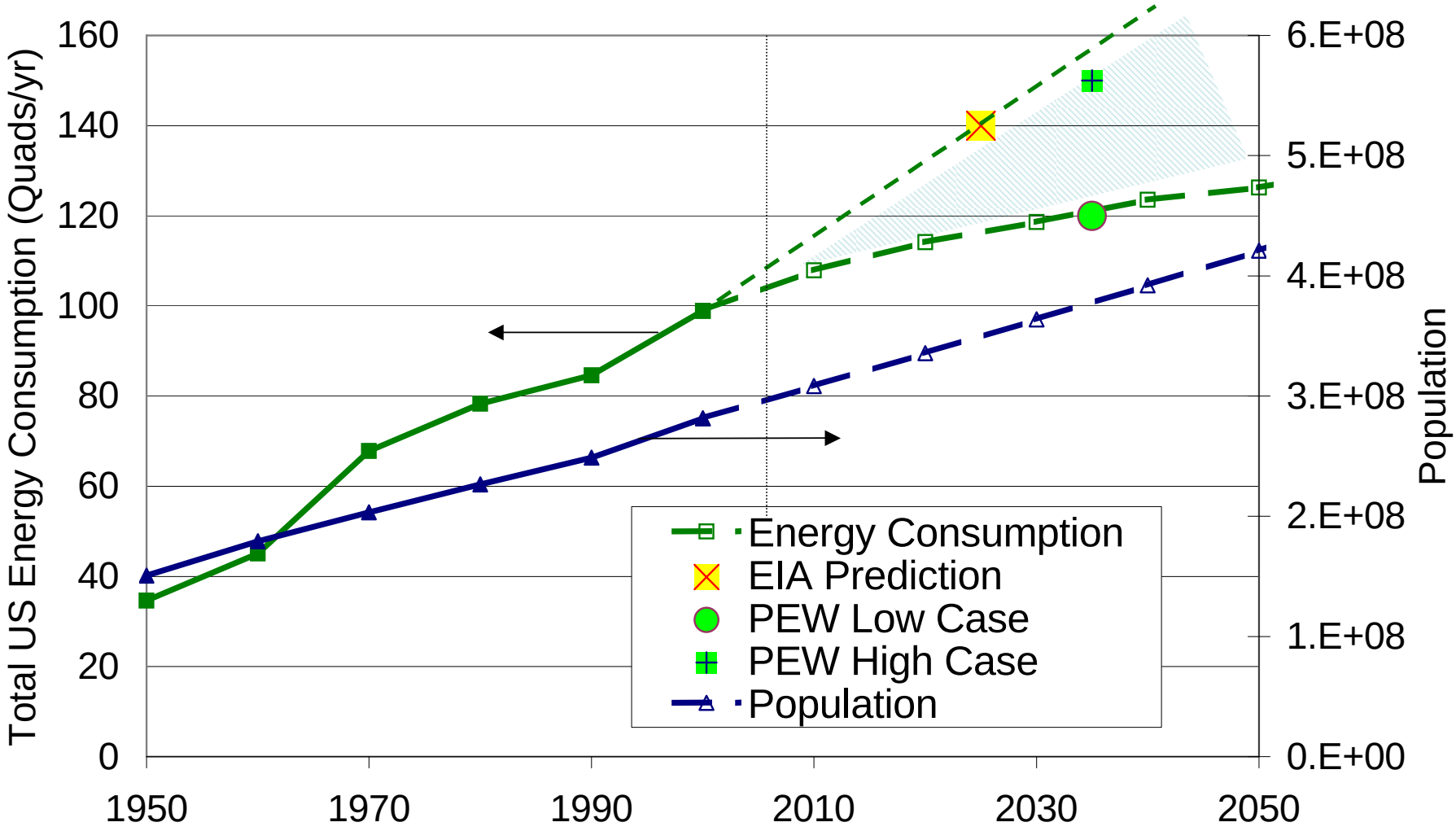
5 February 09

Chris Boyer

Improving Energy Usage

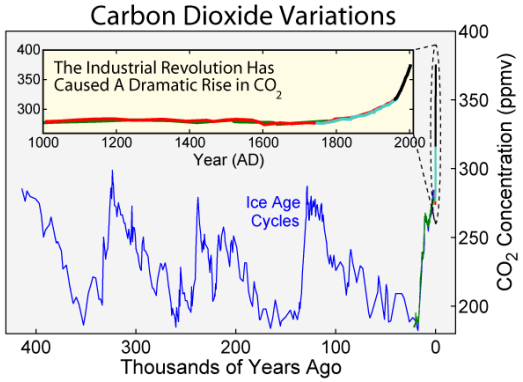


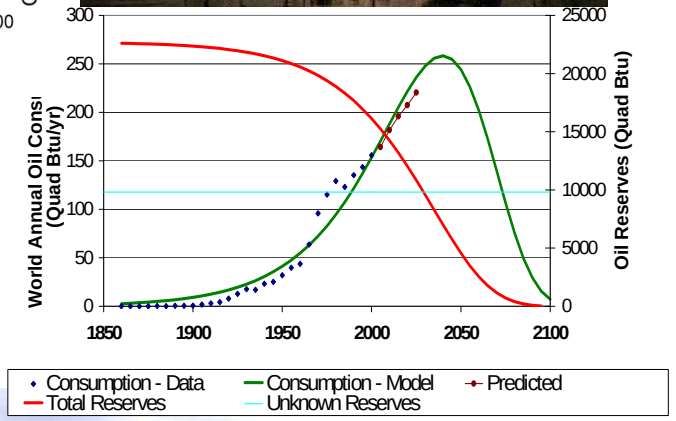
US Energy Demand Growing



The Energy Problem

1. Rising cost of fossil fuel extraction
2. Trade deficit
3. Violent conflicts over finite resources
4. Pollution and climate change
5. Threat of nuclear proliferation and waste disposal



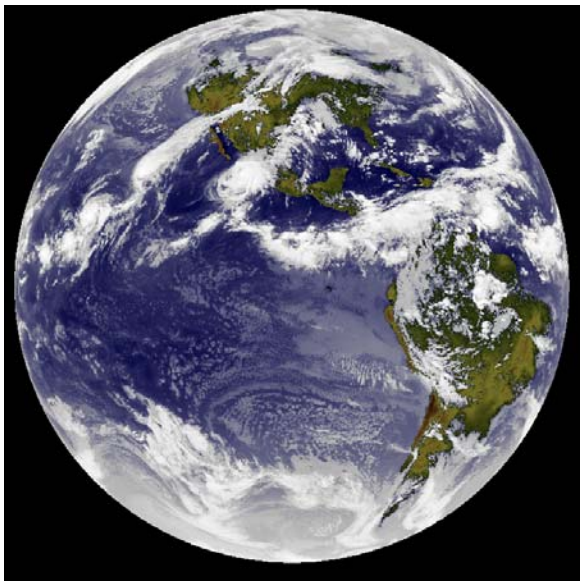


Solar Energy

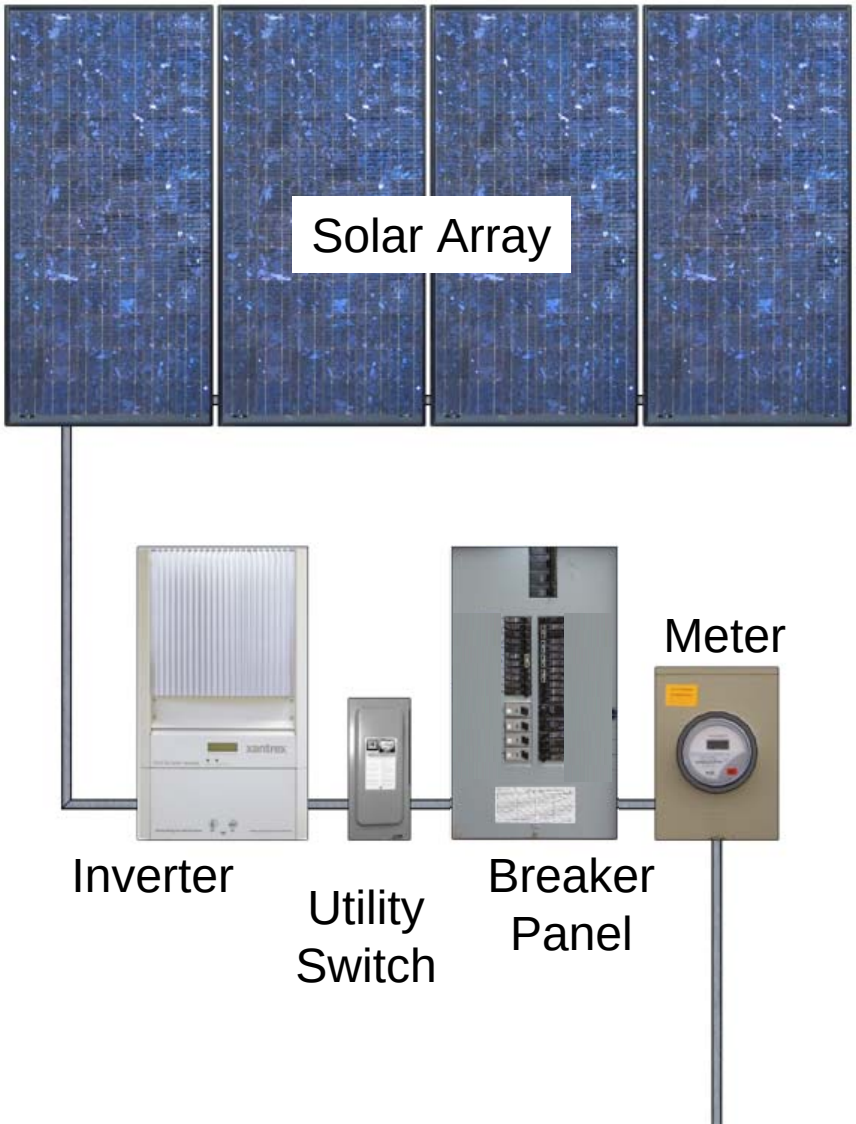
80,000 Terawatts of Solar Power fall on the Earth constantly, compared to 14.5 Terawatts current used for human power.

<u>Ways of Harnessing Solar Energy</u>

- Solar Electricity – Photovolatics (PV)
- Solar Thermal Heating
  - Hot water – residential and commercial
  - Utility Steam & Electricity
  - Cooking
- Solar Building Design
  - Shade & venting
  - Solar heating
- Wind



Grid Tie Components



Battery Systems

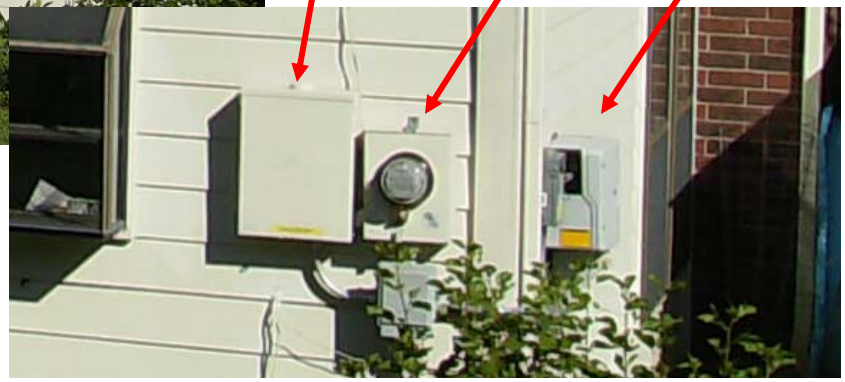
Grid Tie PV System

PV Array

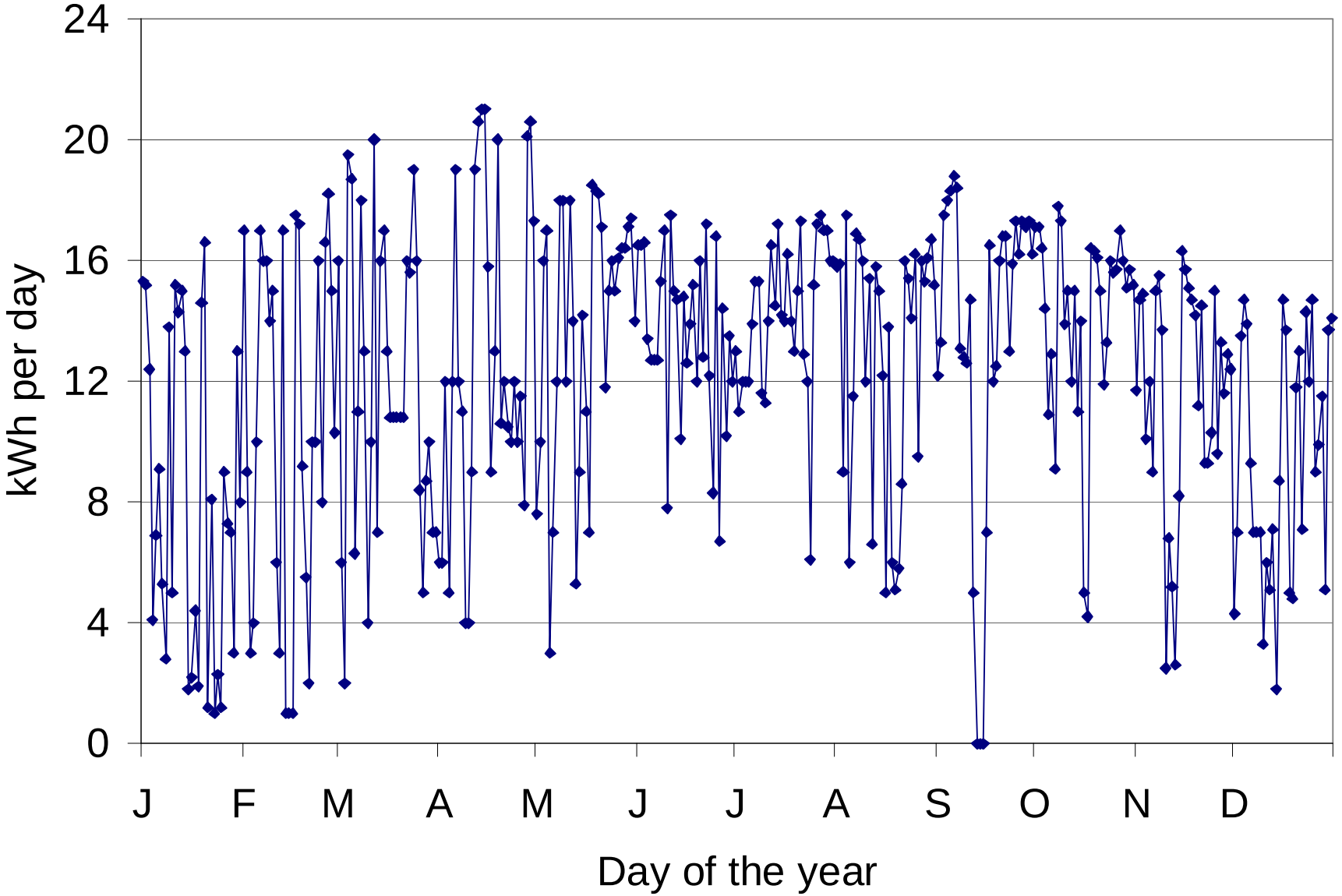
Service panel

Meter

Inverter



Daily Production



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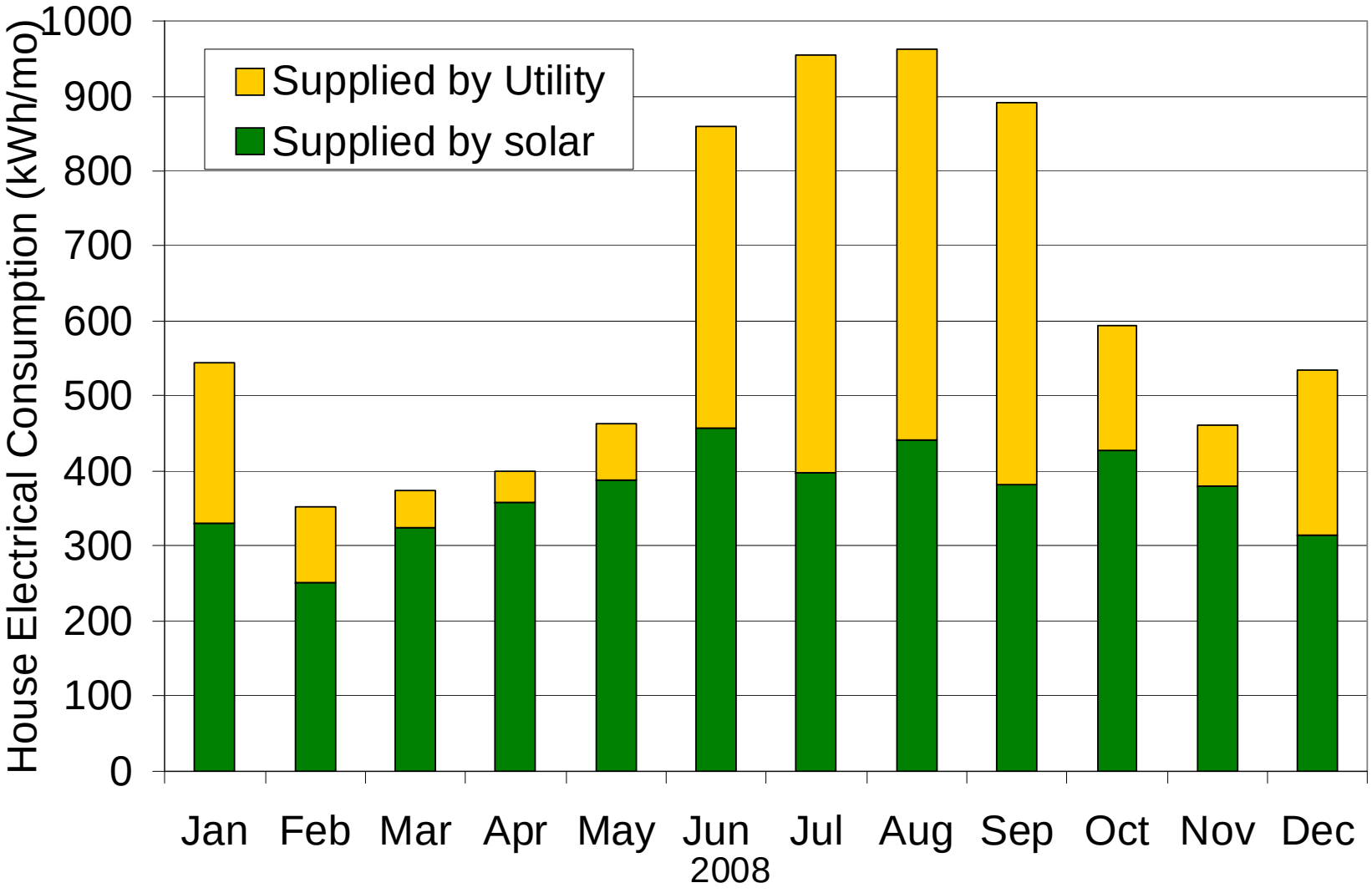
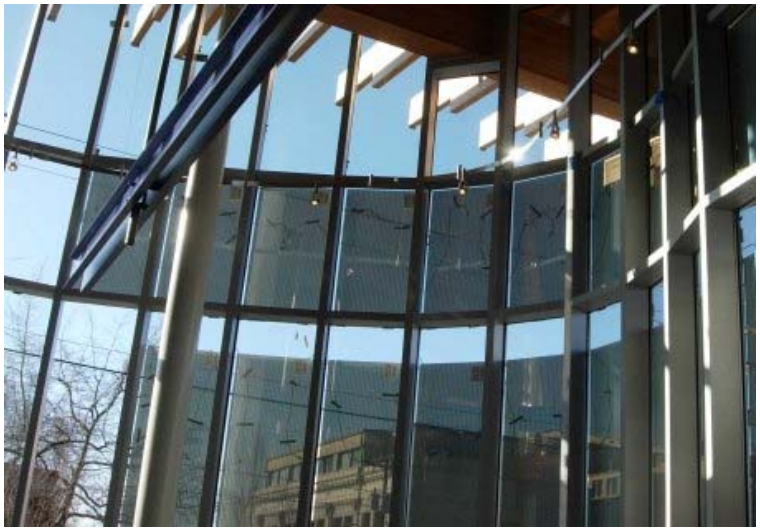
Annual Production & Consumption



What is Your Objective?

- Economics
- Art
- Interest
- Make a statement



What do we have to work with?

Your PV Size will depend on:

- Electric usage
- Available space
- Rebate or incentive limits
- Financing / Budget
- Utility and local restrictions

How Much Space

- Figuring kW and kWh
- Orientation and slope
- Shading
- Module layout
- Roof structure

HOUSTON, TEXAS

kWh per year per kW DC PV		AZIMUTH				
		West	SW	South	SE	East
		270°	225°	180°	135°	90°
TILT	0°	1177	1177	1177	1177	1177
	15°	1170	1247	1275	1238	1159
	30°	1096	1229	1279	1216	1077
	45°	1003	1171	1232	1154	980
	60°	879	1053	1102	1031	856
	90°	596	697	676	681	576

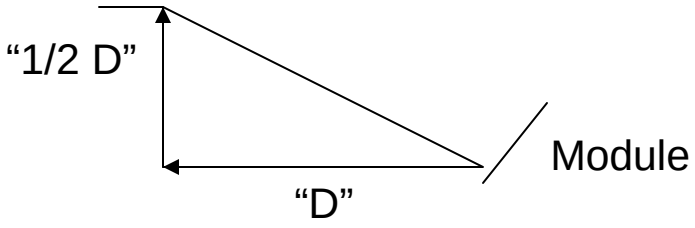
% of Optimum		AZIMUTH				
		West	SW	South	SE	East
		270°	225°	180°	135°	90°
TILT	0°	92.0%	92.0%	92.0%	92.0%	92.0%
	15°	91.5%	97.5%	99.7%	96.8%	90.6%
	30°	85.7%	96.1%	100.0%	95.1%	84.2%
	45°	78.4%	91.6%	96.3%	90.2%	76.6%
	60°	68.7%	82.3%	86.2%	80.6%	66.9%
	90°	46.6%	54.5%	52.9%	53.2%	45.0%

Shading

Special tools can show losses due to shading.

Rule of Thumb

Anything half as high as it is far away is OK.



Matching Electric Usage

- Efficiency first
  - First Review
  - Then Reduce
  - Finally Renew

- Match 75 to 90% of usage
- New “Net Metering Laws for Texas”

- Note: Off-grid systems must be sized for 3 times usage; 2/3rds wasted.

House Made for solar

Solar Made to House

Shaped Panels

PV Array - 15kW

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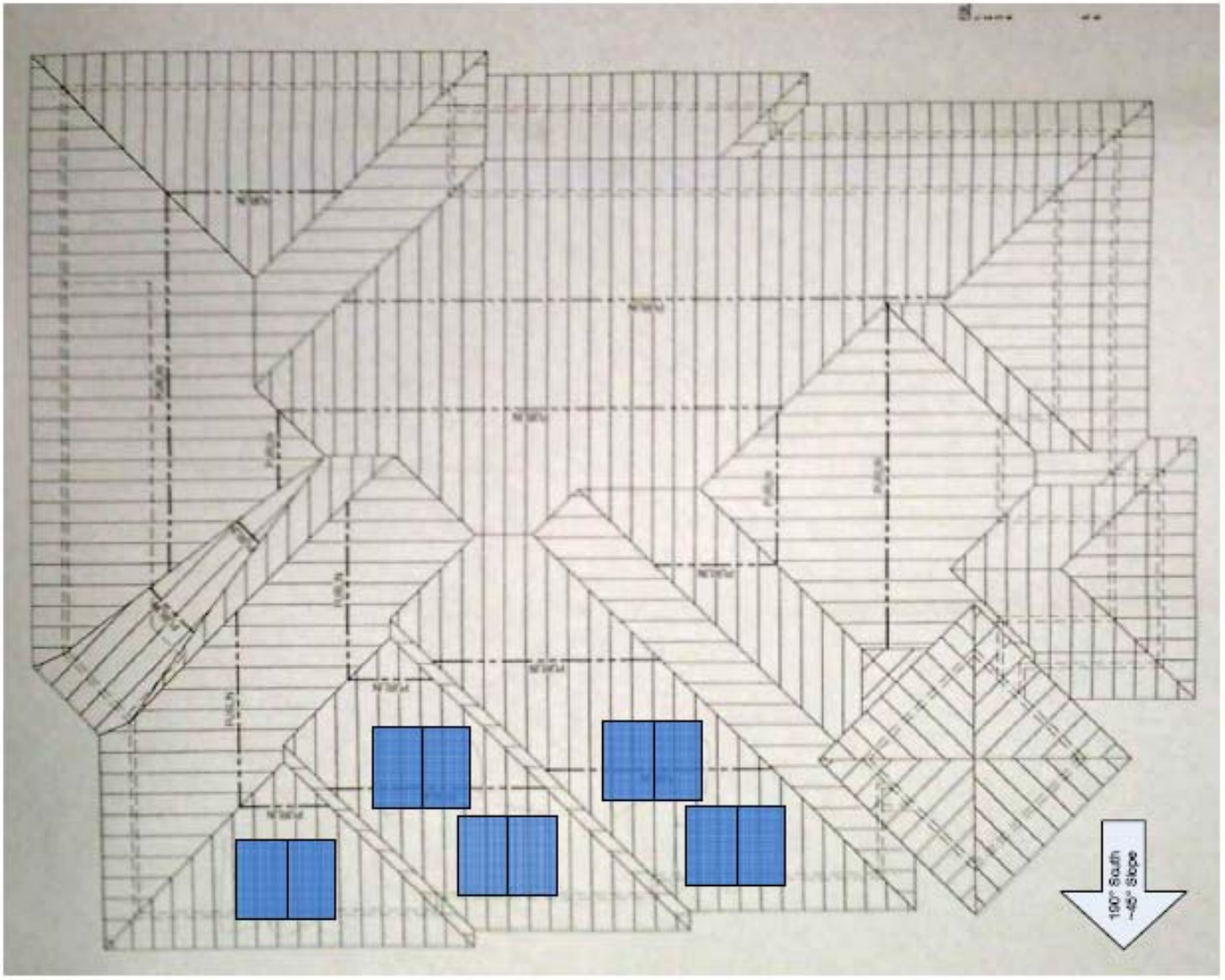
Tilt up on a flat roof.

Try to get 2 kW on 6000 ft²



Solar PV Integrated into Structures

Ballasted Ground Mount

Will Costs Go Down?

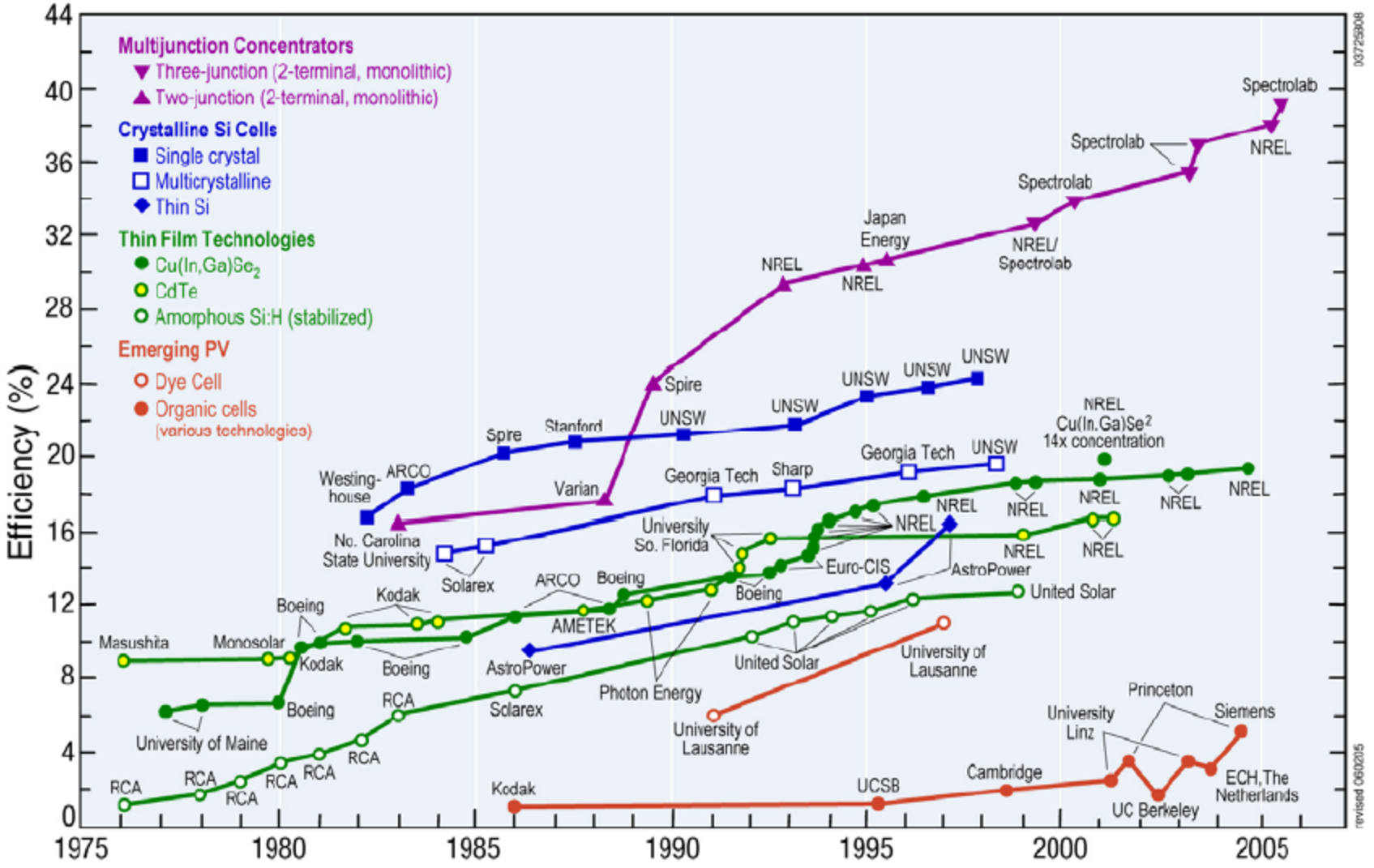
- Silicon
  - 50% higher due to manufacturing shortage
- Thin Film
  - Low efficiency has higher real estate cost
- Plastic / Paint
  - Deterioration
- Concentrated
  - Requires tracking
- Distributed at Buildings vs Utility Solar farms
  - Ads and Disads of each cancel – both equally viable.

Economics

- Cost of a turn-key PV System
  - $7,000/kW large and simple
  - $12,000/kW small and complex
- Rebates & Incentives
- Accelerated depreciation
- Demand billing ($0.70/kWh at day peak)
- Value appreciation of the Building
- Electric rates predicted to increase 10% per yr
- Payback 5 to 30 years
- Cost of PV electricity $0.04 to $0.56 /kWh

Residential is economical in Rebate areas. Most commercial is economical.

Improvements in Cell Efficiency



Advancing Solar PV Technology

New Materials

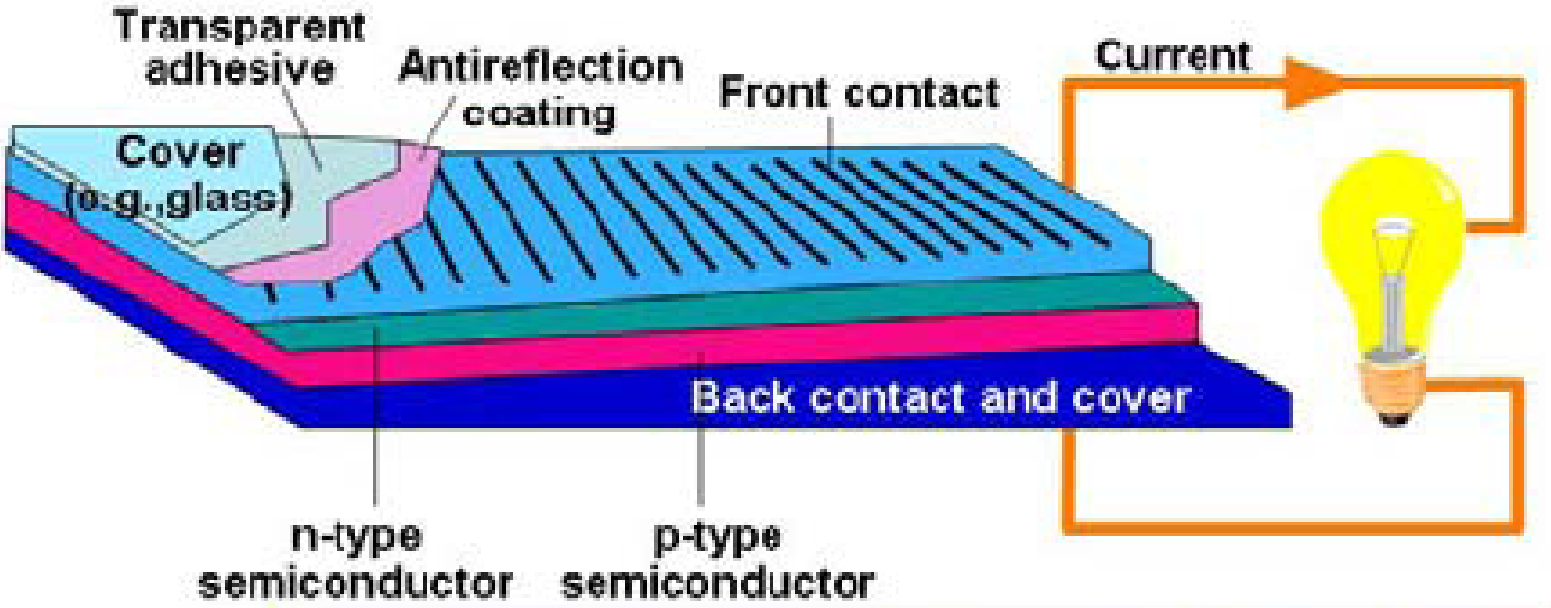
- Silicon
  - Crystalline
  - Polycrystalline
  - Amorphous
  - Ribbon
  - Nanocrystalline
- CdTe
- GaAs
- CIS/CIGS
- Dye-Sensitized
- Organic

New Structures

- Wafer P-N Junction
- Thin Film P-N Junction
- Multi-Junction
- Quantum Dots
- Photoelectrochemical

Related Technologies
-digital camera
-LEDs
-Solid state lasers

P-N Junction Solar Cell Structure



$$\text{Solar cell efficiency (\%)} = \frac{\text{Power out (W)} \times 100\%}{\text{Area (m}^2\text{)} \times 1000\ \text{W/m}^2}$$

10% efficiency = 100 W/m^2 or 10 W/ft^2

Photochemical Cell Structure

Structure for high-efficiency (50%) organic PV cell based on a nanostructured substrate onto which thin layers of molecular multi-junctions are grown and anchored onto the nanostructure surface. The red circle denotes an electron acceptor; the blue square, an electron donor; and the yellow circle, a metal nanoparticle.