PV prospects

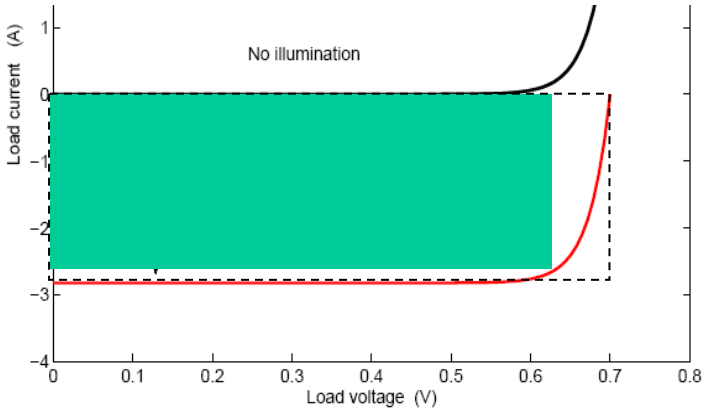
LECTURE 11

- optimizing conversion efficiency
- Si cell costs
- thin-film cells
- North Vancouver PV case study

Sec. 7.5.1

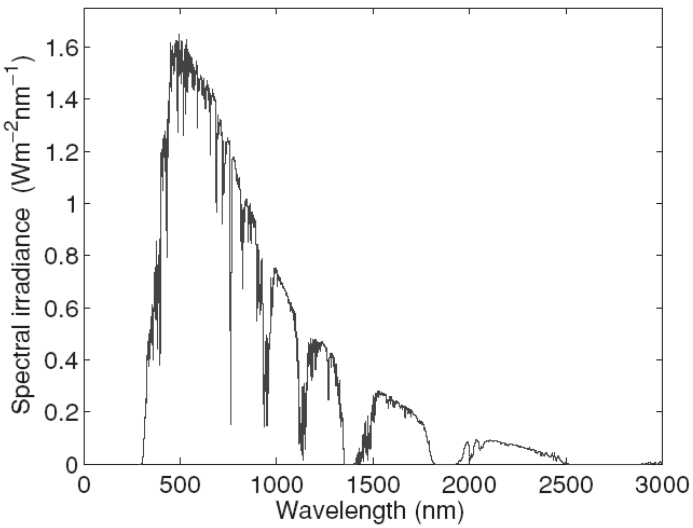
PV Efficiency

OUTPUT:



$$P_{mp} = J_{mp}V_{mp} \equiv FF\, J_{sc}V_{oc}$$

INPUT:



P_{in} = ?

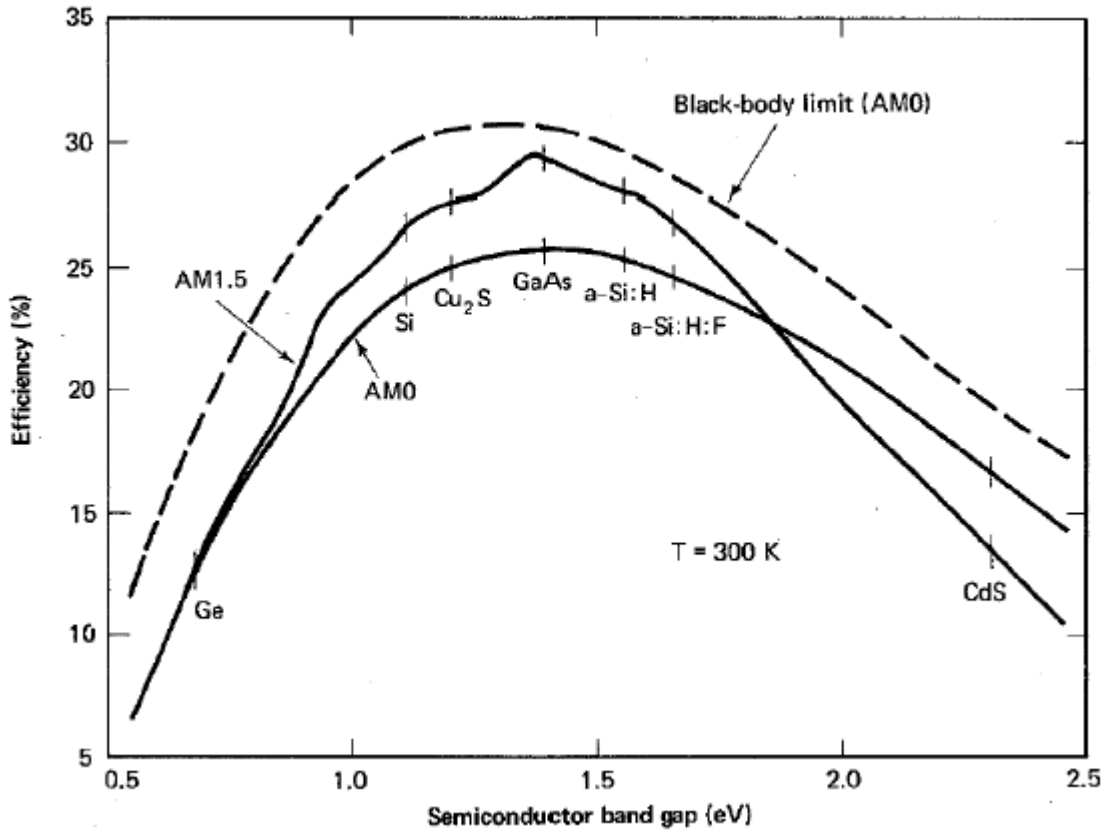
EFFICIENCY:

$$\eta_{pv} = \frac{FF\, J_{sc}V_{oc}}{\mathcal{S}_{\mathrm{AM1.5G}}}$$

Sec. 7.5.1

Efficiency and bandgap

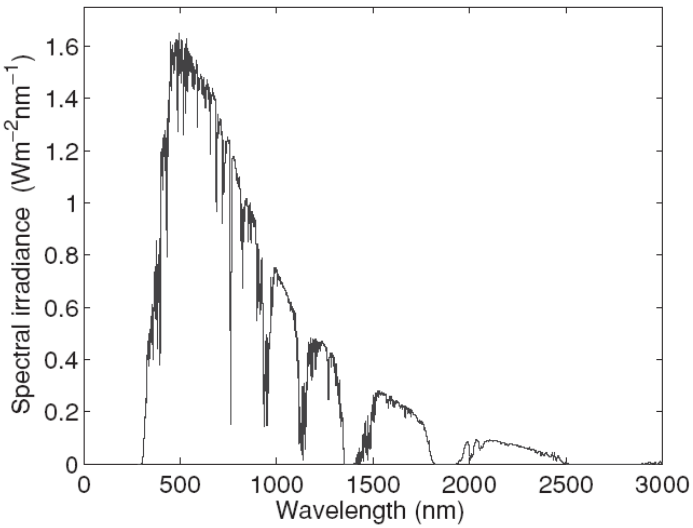
$$\eta_{pv} = \frac{FF\, J_{sc} V_{oc}}{\mathcal{S}_{\mathrm{AM1.5G}}}$$



Why is there a maximum in the relationship?

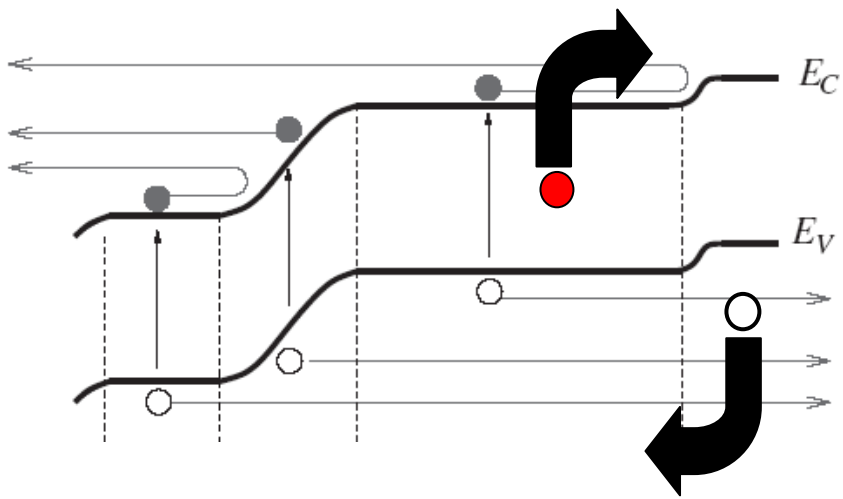
Optimum bandgap

$$\eta_{pv} = \frac{FF\, J_{sc} V_{oc}}{\mathcal{S}_{\mathrm{AM1.5G}}}$$



$$J_{\mathrm{Ph}} = \sum_{\mathrm{AM1.5G}} J_{\mathrm{Ph}}(\lambda)$$

$J_{sc} = J_{Ph} \downarrow$ as $E_g \uparrow$

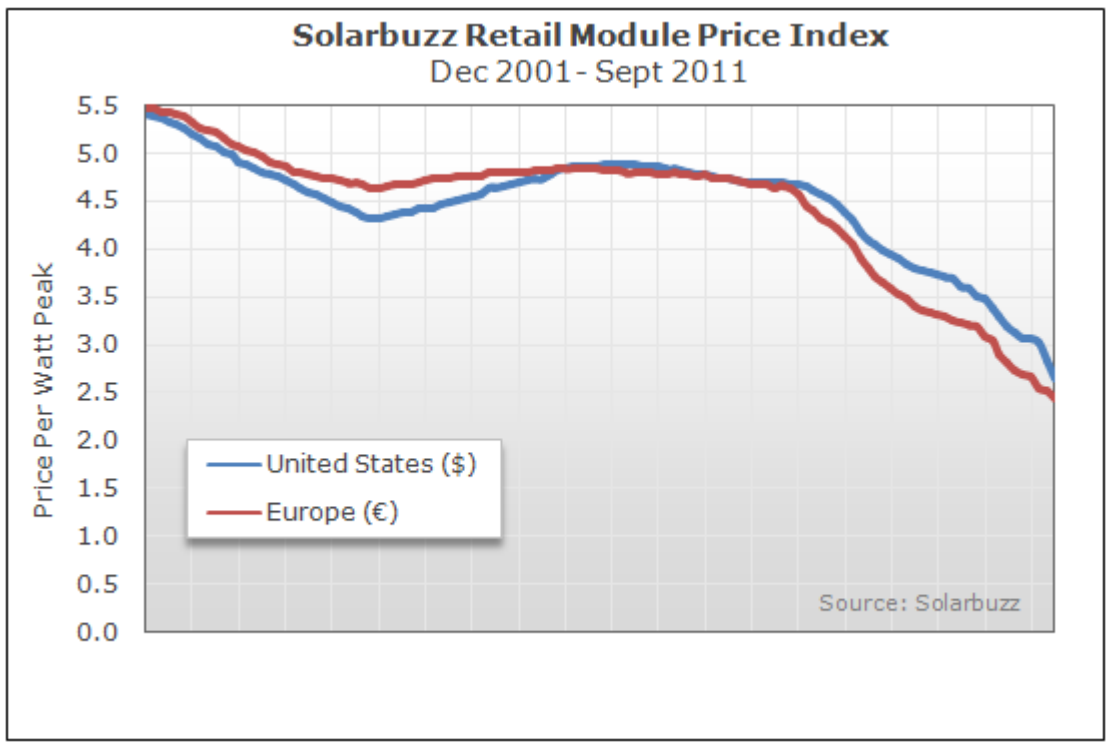


$$V_{oc} = V_{\mathrm{th}} \ln \frac{J_{\mathrm{Ph}} + J_0}{J_0}$$

$J_{dark} \downarrow$ as $E_g \uparrow$

V_{oc} as $E_g \uparrow$

Cost of PV modules



The lowest retail price for a multicrystalline silicon solar module is $1.61 per watt (€1.13 per watt) from a US retailer. The lowest retail price for a monocrystalline silicon module is $1.48 per watt (€1.04 per watt), from an Asian retailer. Brand, technical attributes, and certifications do matter. The lowest thin film module price is at $1.40 per watt (€0.98 per watt) from a US-based retailer.

http://www.solarbuzz.com/Moduleprices.htm

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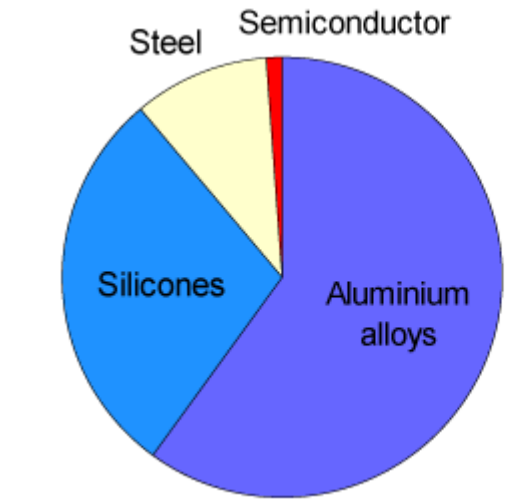
Silicon material

$$SiO_2 + 2C \longrightarrow Si + 2CO$$

Metallurgical grade Si



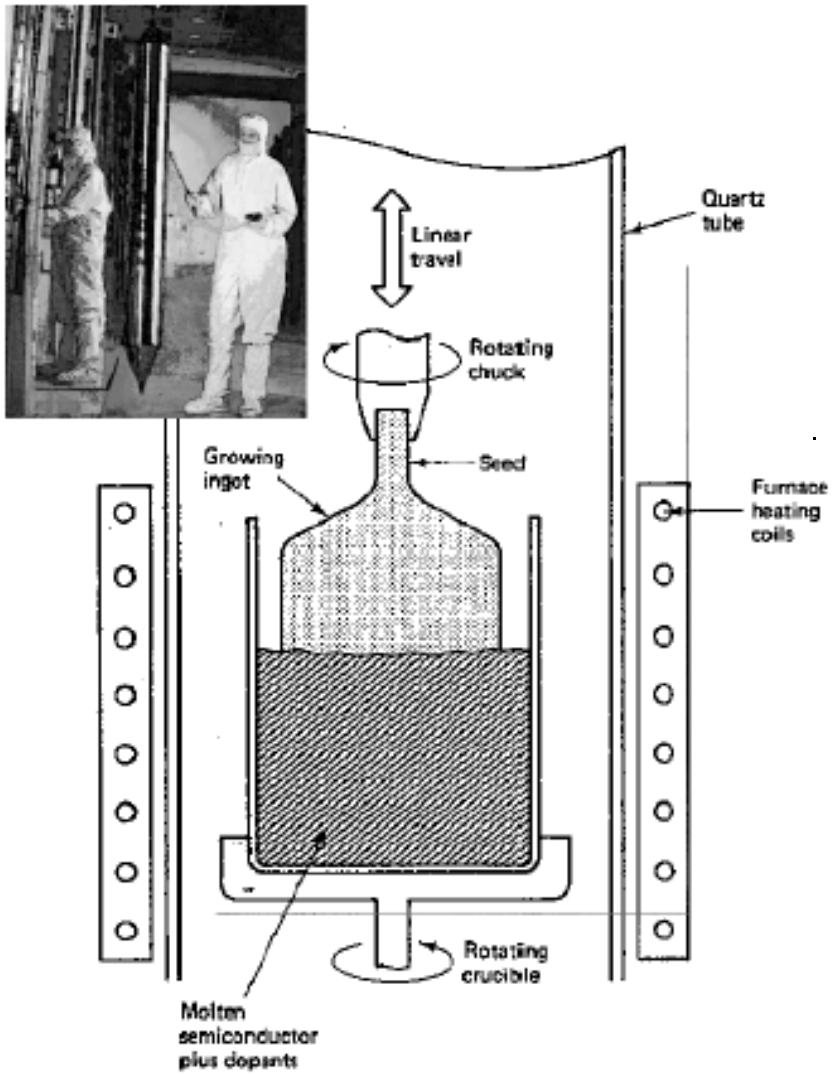
Total production ~ 900 000 tonnes/p.a.

Element	Concentration (ppma)	
Al	1200-4000	X
B	37-45	X
P	27-30	X
Ca	590	
Cr	50-140	
Cu	24-90	X
Fe	1600-3000	X
Mn	70-80	
Mo	<10	
Ni	40-80	
Ti	150-200	
V	100-200	
Zr	30	

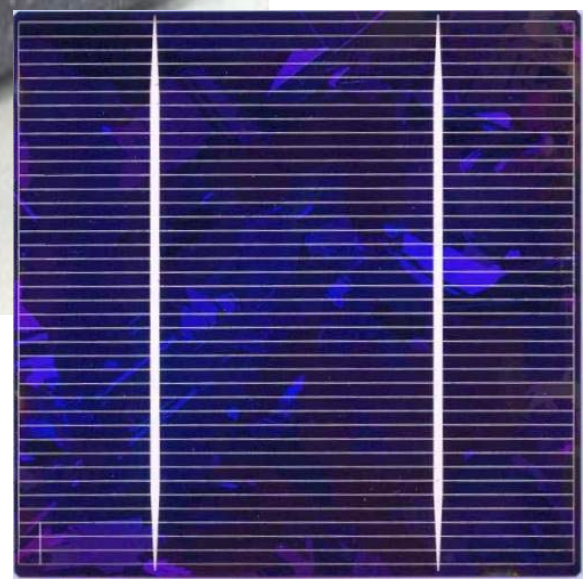
Semiconductor grade Si

$$Si + 3HCl \leftrightarrow SiHCl_3 + H_2$$

Single-crystal Si modules

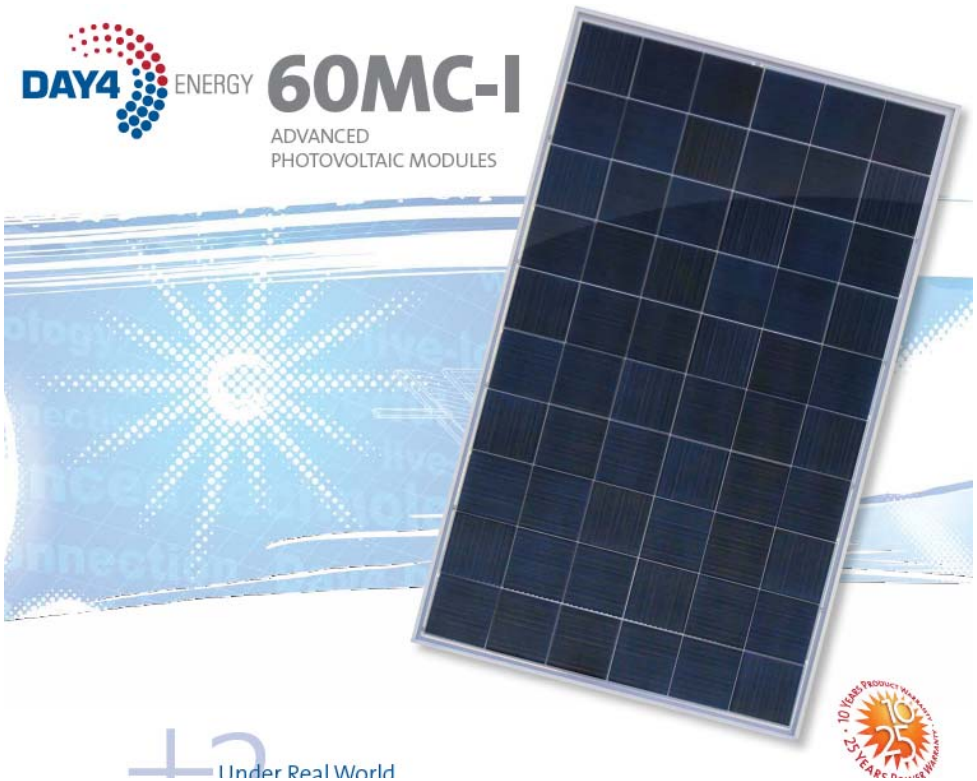


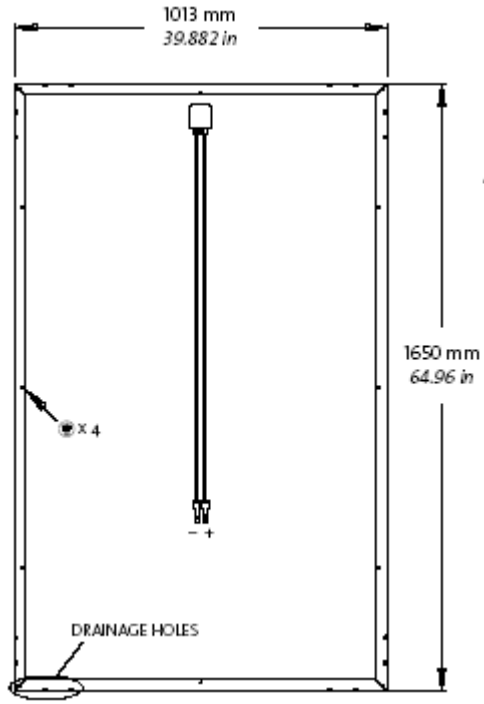
mc-Si solar cells



http://www.udel.edu/igert/pvcdrom/index.html

Made in BC at Day4 Energy



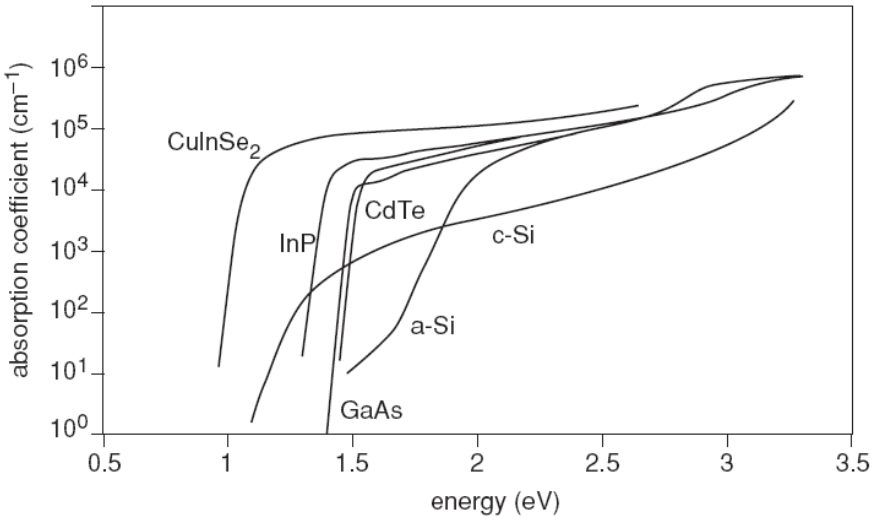


Typical Electrical Performance at STC (1000W/m², AM 1.5 Spectrum, cell temperature 25°C)

Power Class	Watts	225	230	235	240	245*	250*
Peak Power (Wp)†	Watts	225	230	235	240	245	250
Max. Power Voltage (V_{mp})	Volts	29.47	29.52	29.77	30.03	30.29	30.55
Max. Power Current (I_{mp})	Amps	7.62	7.80	7.89	7.98	8.08	8.17
Open Circuit Voltage (V_{oc})	Volts	36.48	36.71	36.90	37.12	37.32	37.54
Short Circuit Current (I_{sc})	Amps	8.12	8.32	8.42	8.54	8.58	8.64

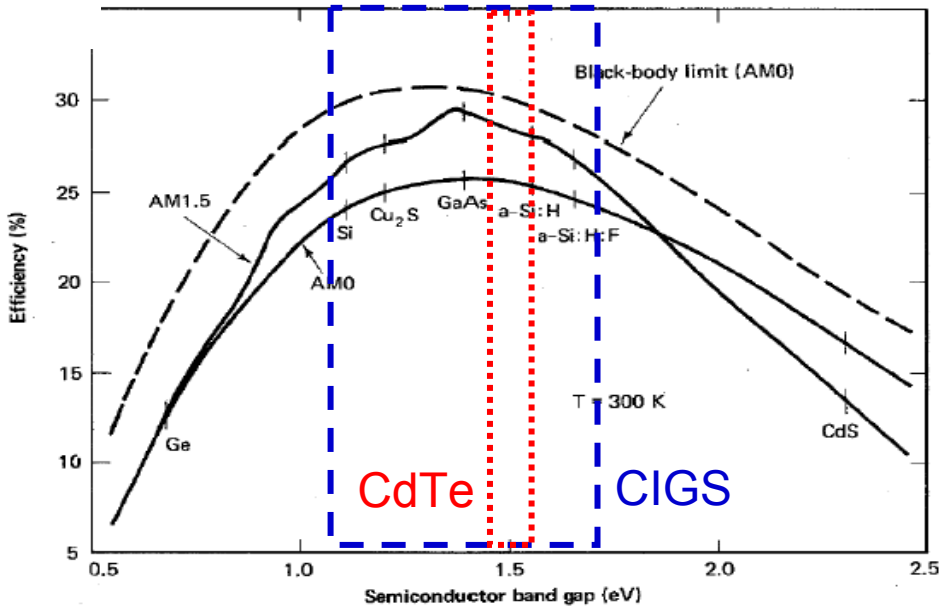
Overall efficiency and cost?

Alternatives to Si: thin-film possibilities

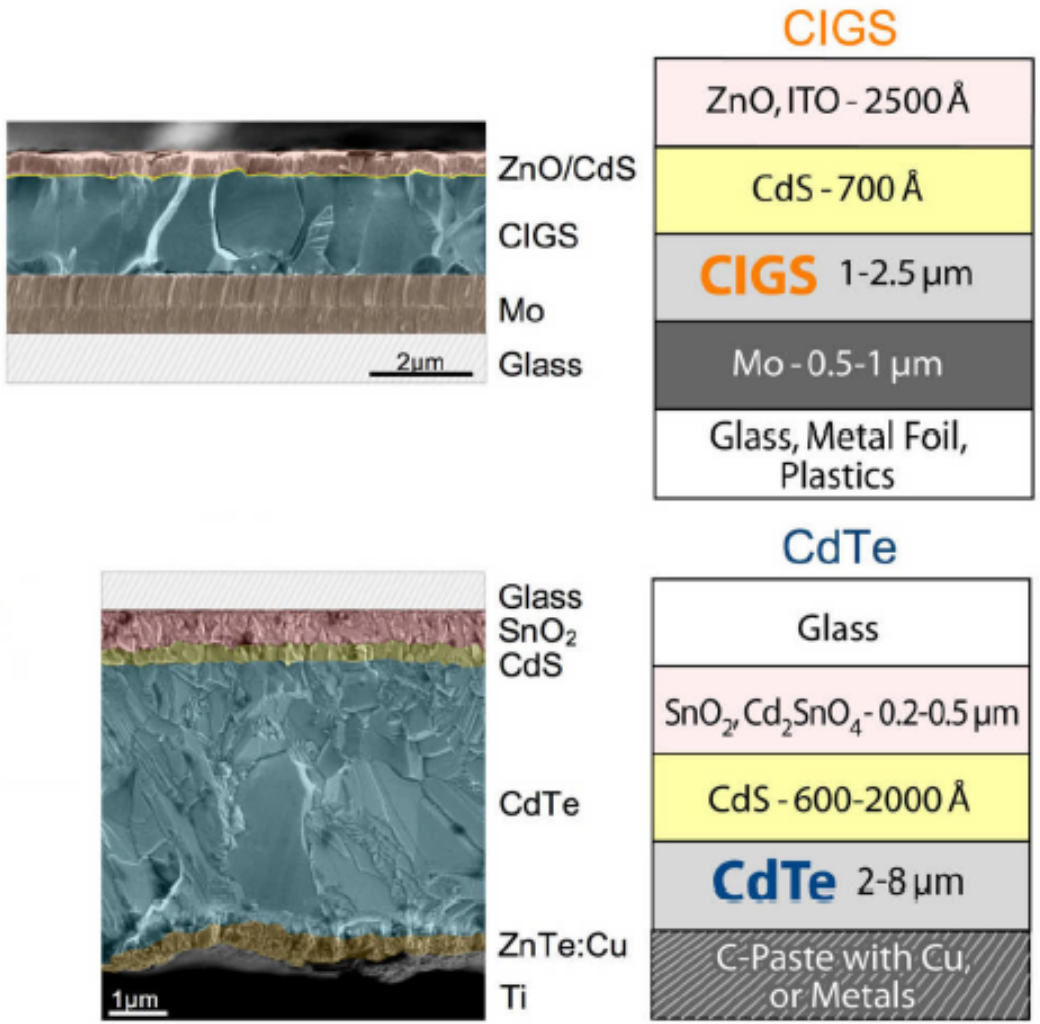


High absorption coefficient

Near-optimum bandgap



CIGS and CdTe: thin-film contenders

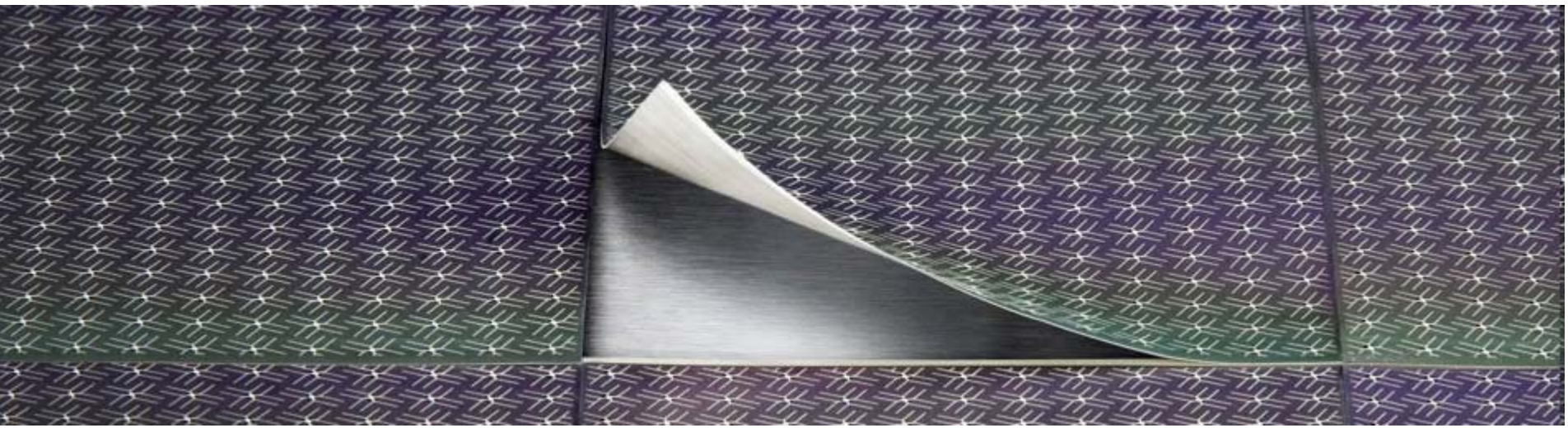


Noufi and Zweibel, IEEE 4th World conf on PEC, 317-320, 2006

Towards commercial CIGS: Nanosolar

NREL Certifies 15.3% Nanosolar Foil Efficiency

By Nanosolar Communications - September 9, 2009



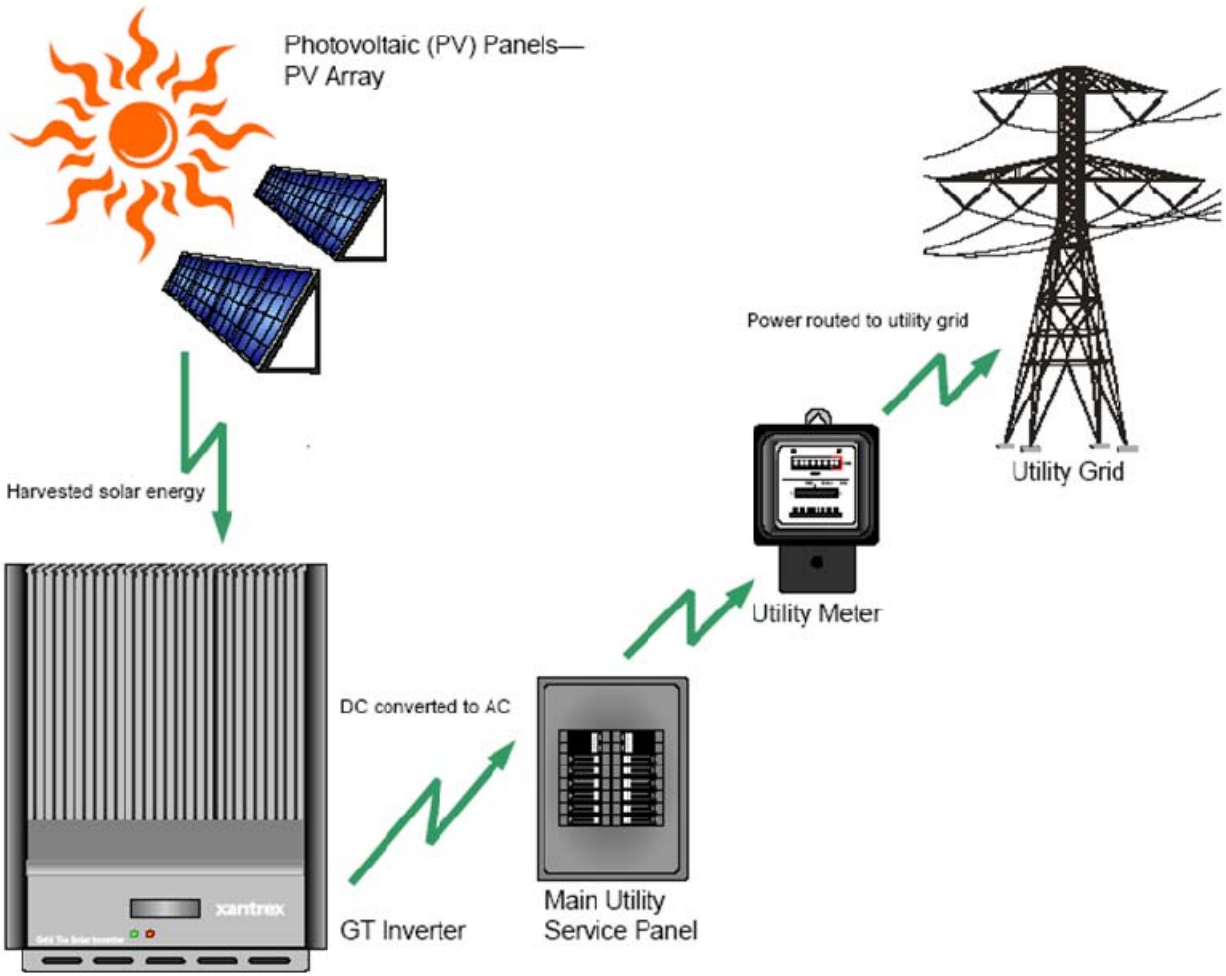
http://www.nanosolar.com/technology

Commercial CdTe: First Solar

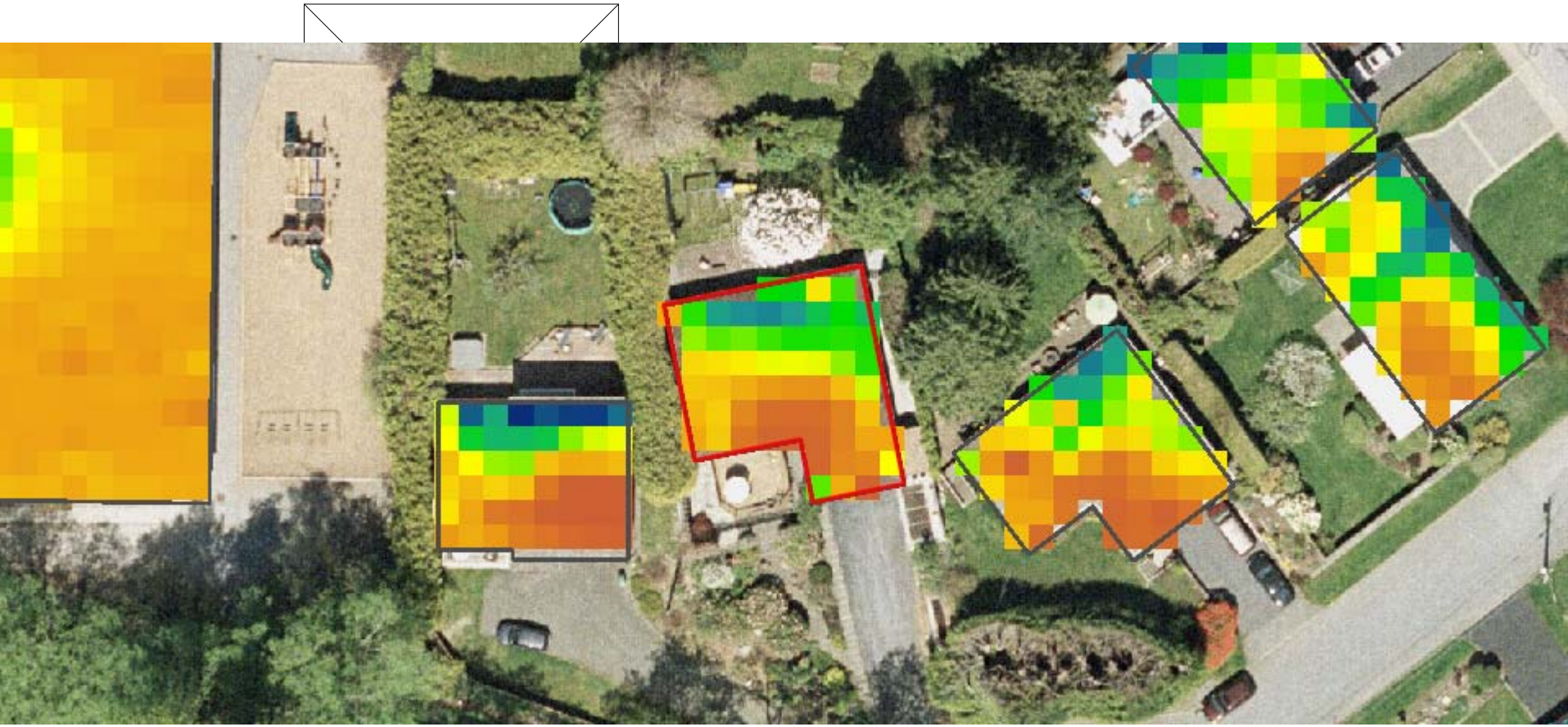
“Before First Solar's manufacturing innovations, cadmium-telluride photovoltaic cells were the size of postage stamps; now the company makes them as big as window panes.”

http://spectrum.ieee.org/energy/renewables/first-solar-quest-for-the-1-watt

PV case study: domestic-grid tie-in

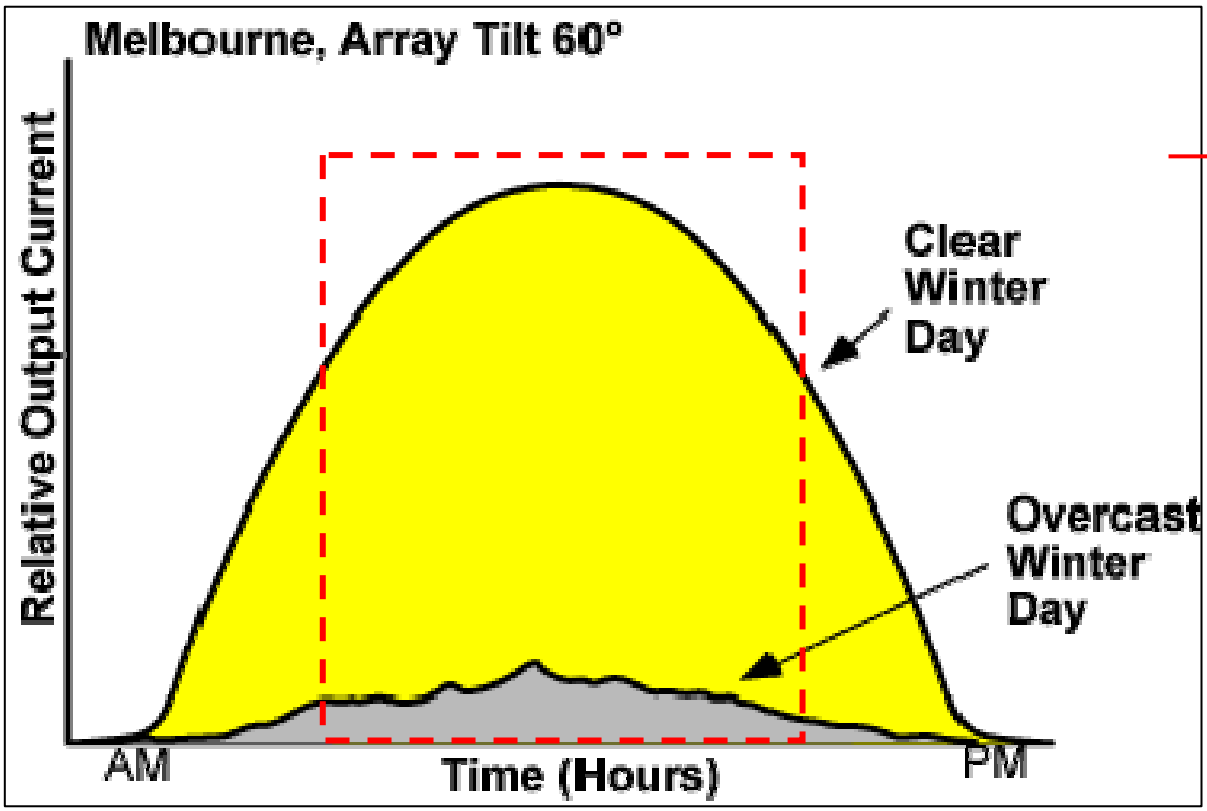


North Vancouver residence



http://www.geoweb.dnv.org/applications/solarapp/

Peak-sun hours



Rated output at Peak Sun

Peak-sun hours (winter max.)

PV incentive: sample calculation

1174 Kendal Place: Rooftop matrix of irradiance (Mean Peak-Sun hours/day)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	2.2	2.2	3.6	2.9	0.0	0.0	0.0
4.5	3.1	2.4	2.2	2.2	2.3	2.7	2.9	2.4	0.0	0.0
0.0	3.6	3.4	3.5	3.4	3.2	3.1	3.0	2.8	0.0	0.0
0.0	4.1	4.0	4.0	3.9	3.8	3.8	3.3	2.9	0.0	0.0
0.0	4.2	4.2	4.4	4.6	4.6	4.5	4.1	3.3	0.0	0.0
0.0	4.3	4.0	4.6	4.8	4.7	4.7	4.6	4.0	0.0	0.0
0.0	4.4	4.0	4.7	4.8	4.7	4.7	4.6	4.3	4.1	0.0
0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5	4.5	3.5	0.0
0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.2	4.8	4.6	4.4
4.1	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Min irradiance h/d	Power rating W/mod	Number of modules	PV energy generated kWh/d	Inverter efficiency	AC energy generated kWh/d	Net-metering $/kWh	Savings $/year	Module cost $	Array cost $	Inverter cost $	Miscell. costs $	Total cost $	Payback time yr
Array	4.7	240	8	9.0	0.94	8.5	0.07	217	794	6352	1772	2031	10155	46.9
Hydro ↑	4.7	240	8	9.0	0.94	8.5	0.14	433	794	6352	1772	2031	10155	23.4
Cells ↓	4.7	240	8	9.0	0.94	8.5	0.14	433	240	1920	1772	923	4615	10.6