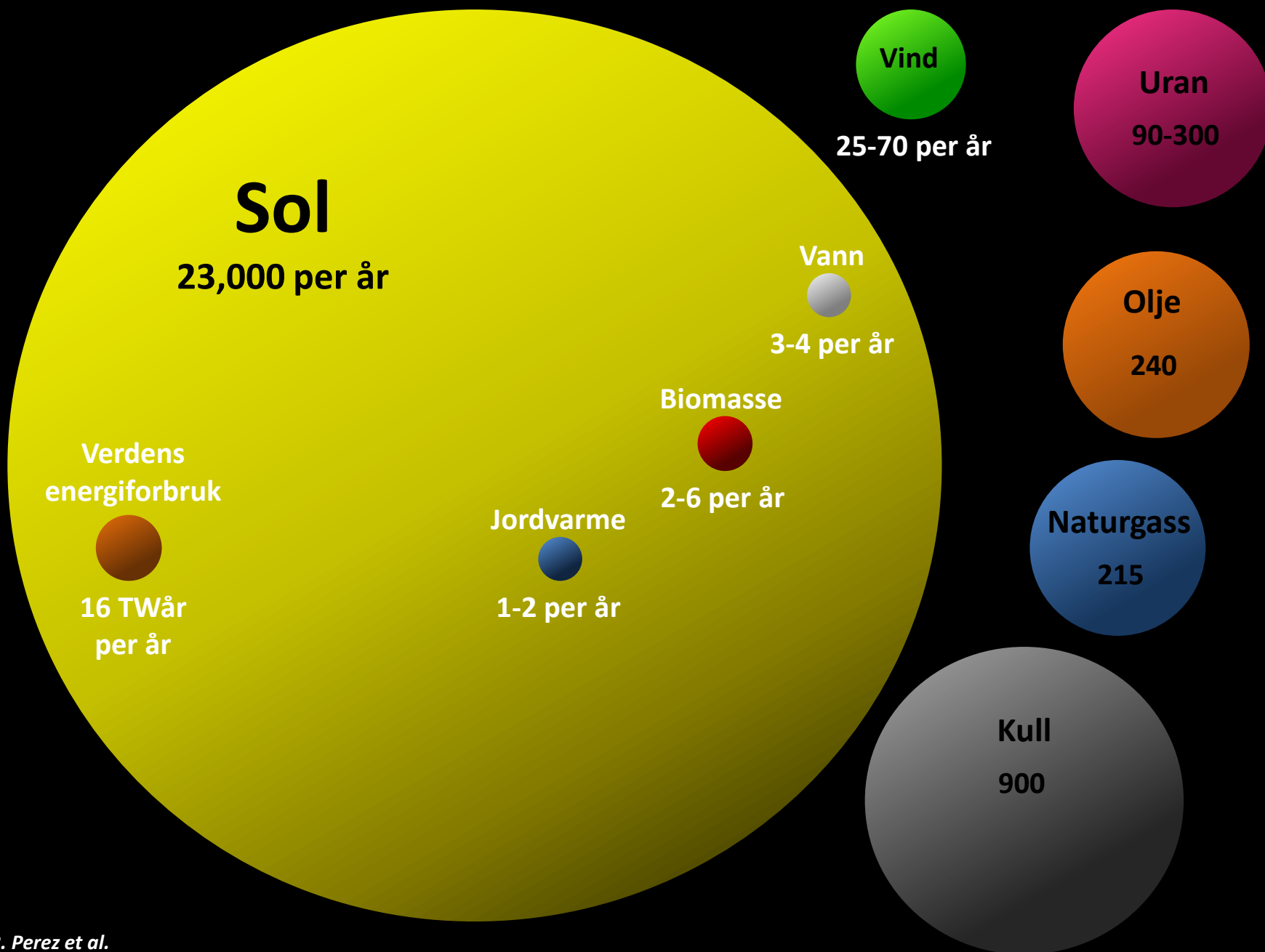
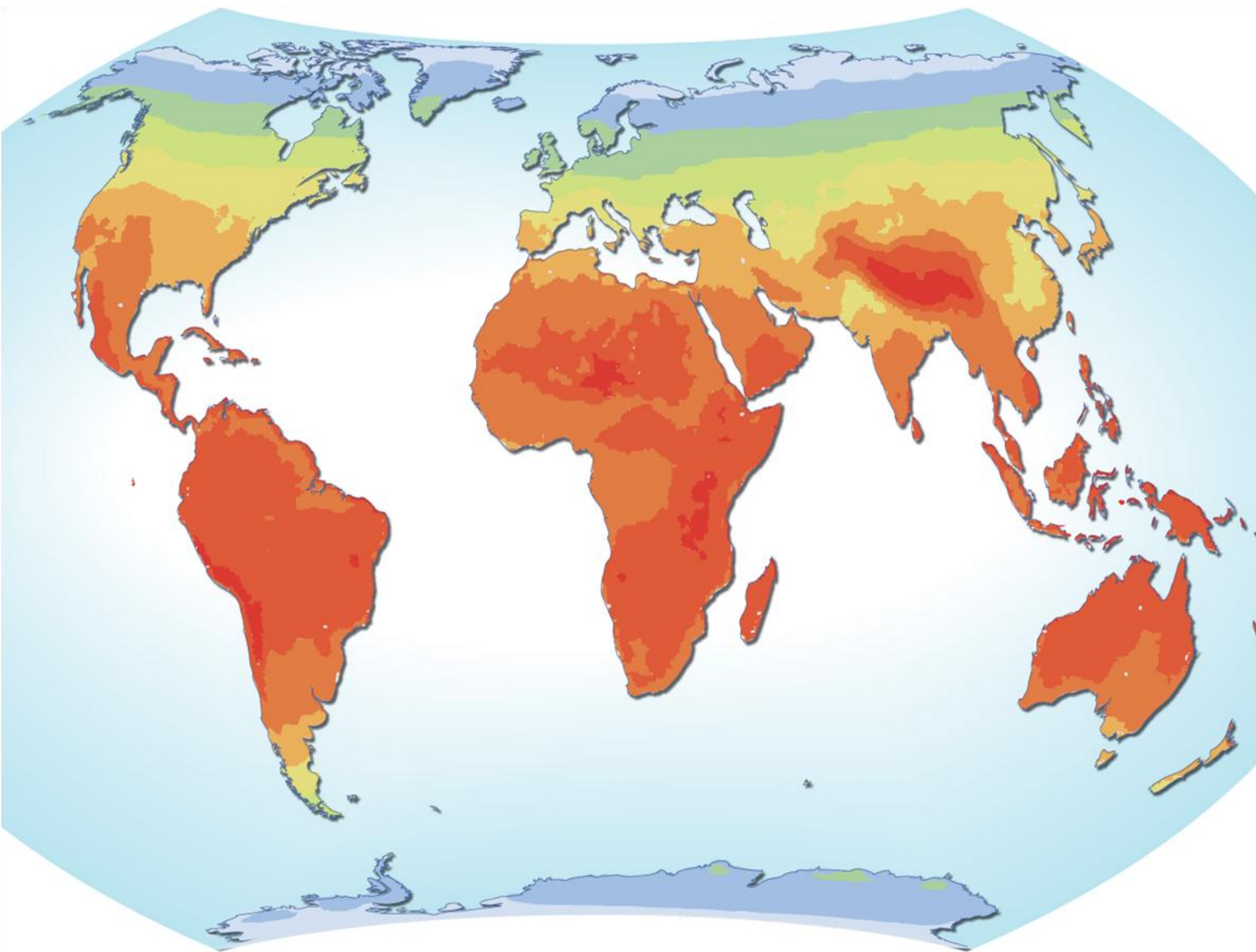


Nye materialer til solceller: Bare en kuriositet?

Per-Anders Hansen
Kjemisk institutt
Universitetet i Oslo







Average annual
ground solar
energy (1983-2005)



7.5

7

6

5

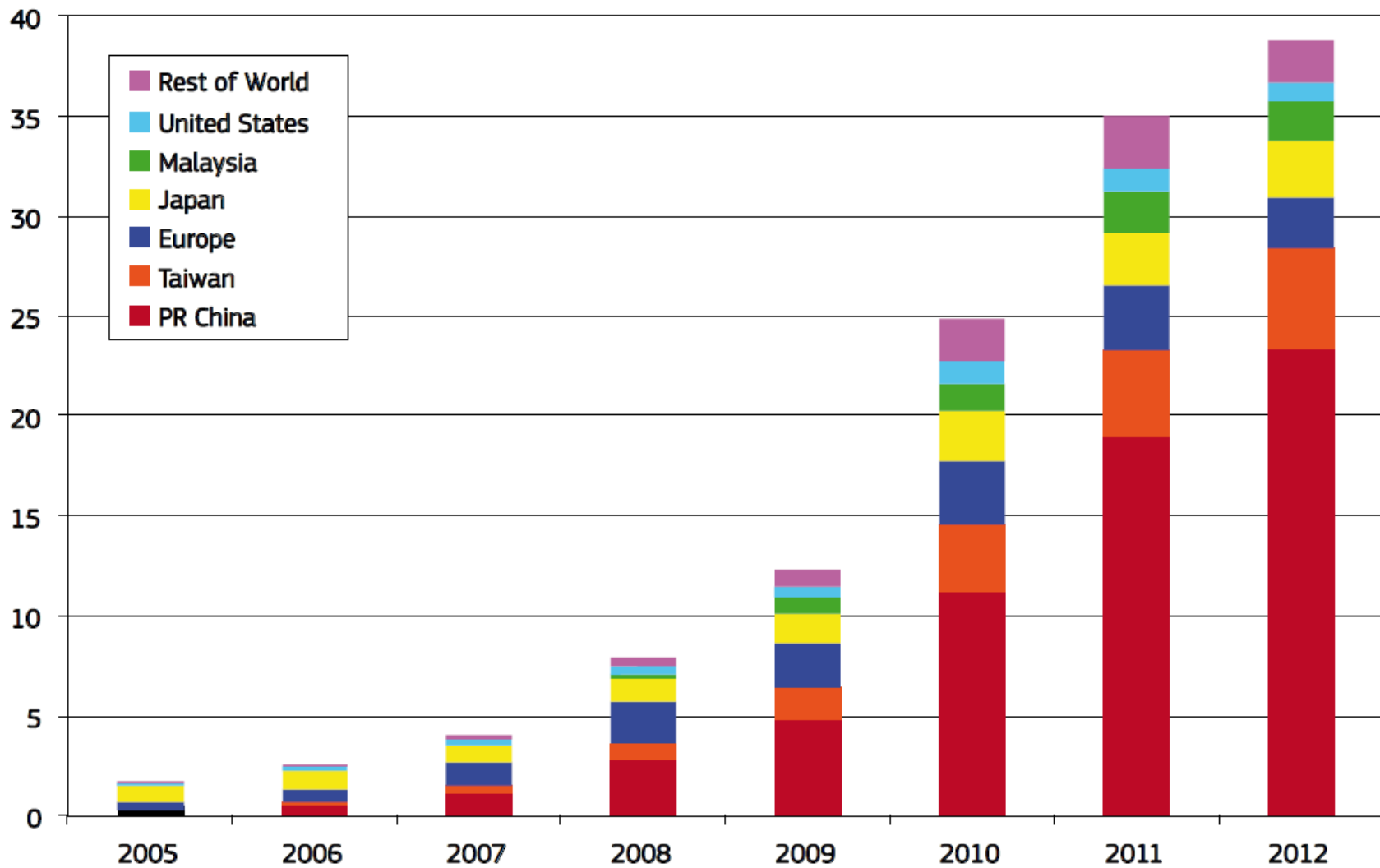
4

3

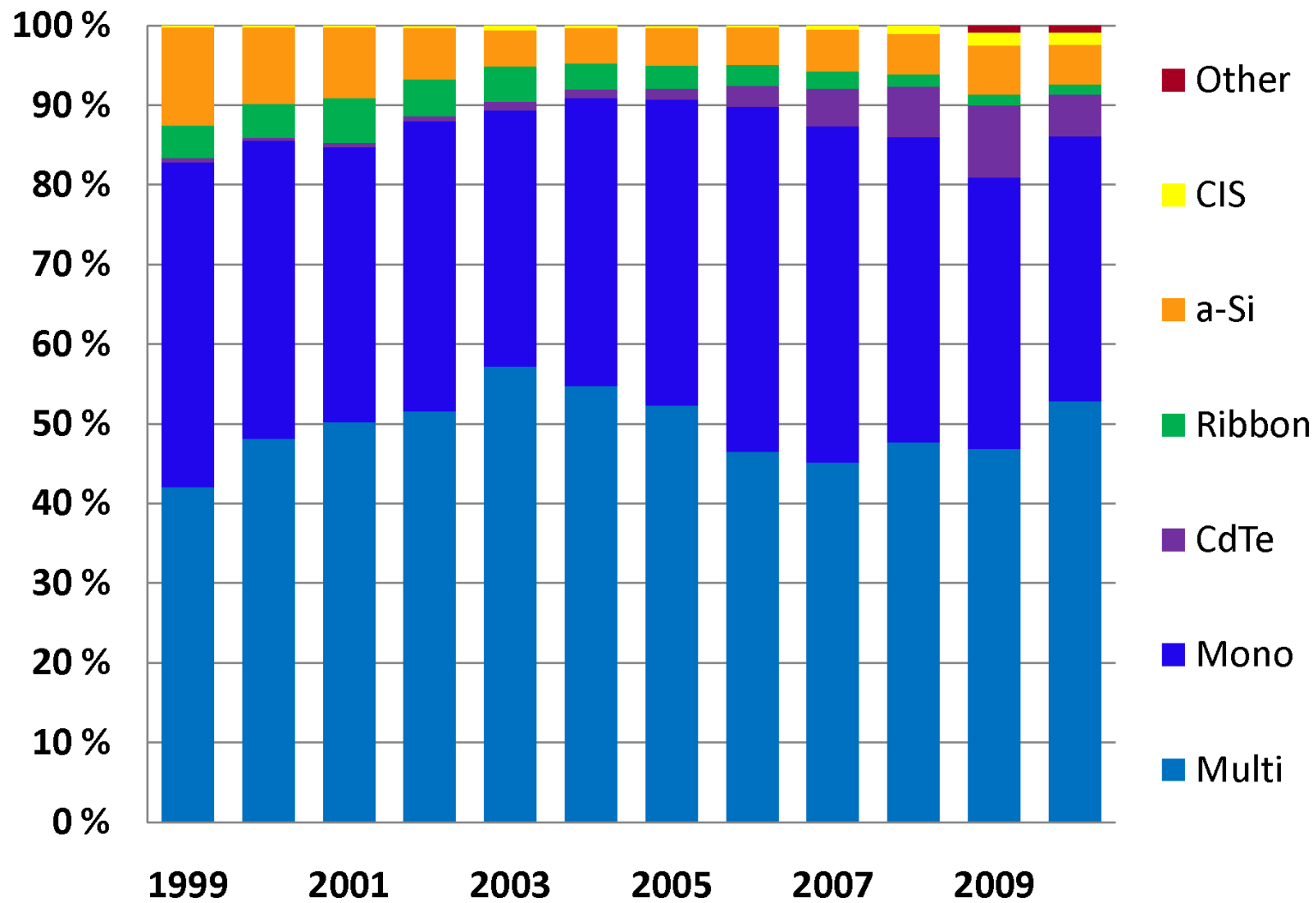
Clear sky insolation
incident, horizontal
surface (kWh/m²/day)

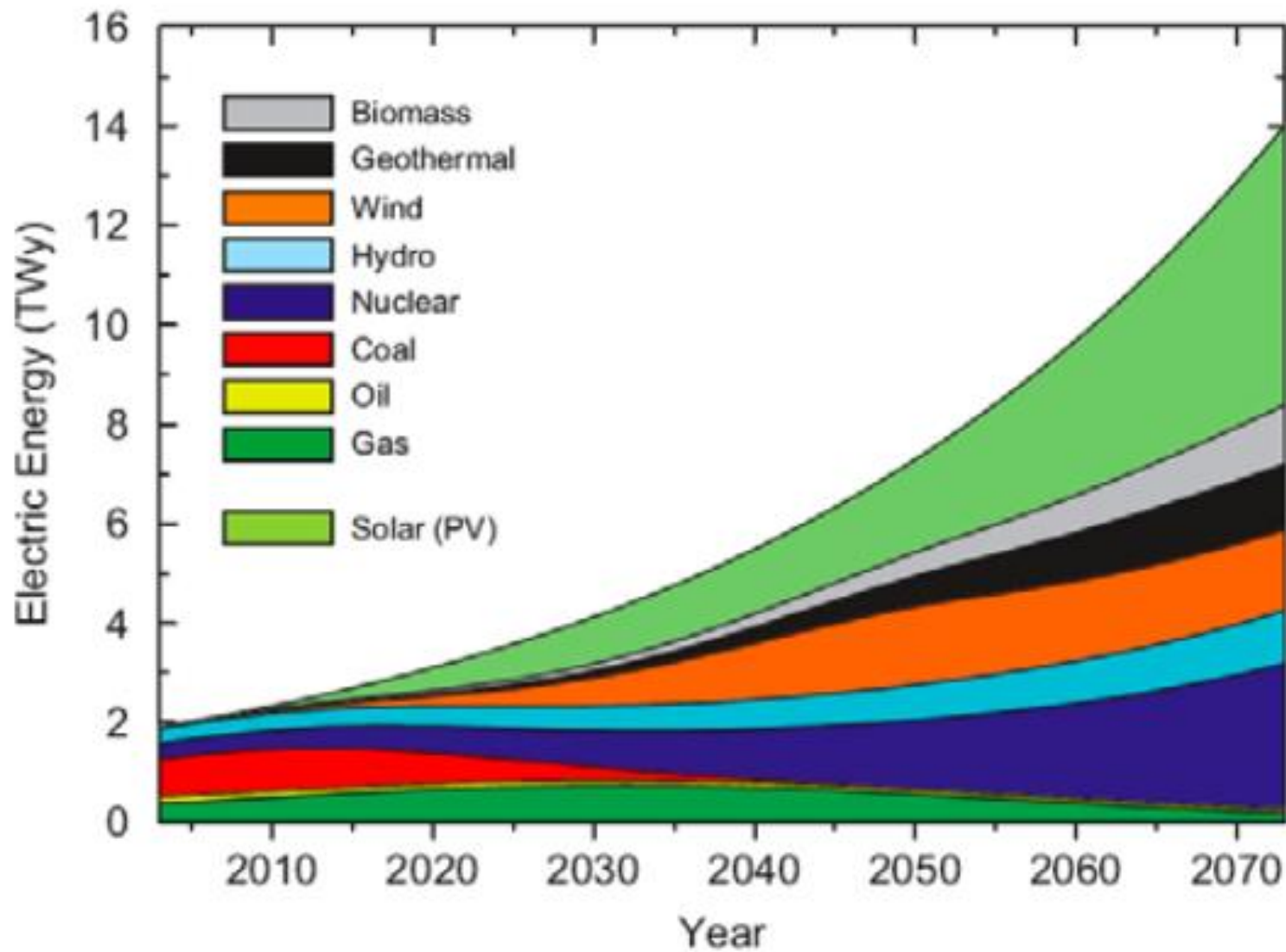
Source: NASA 2008

Annual Production [GW]



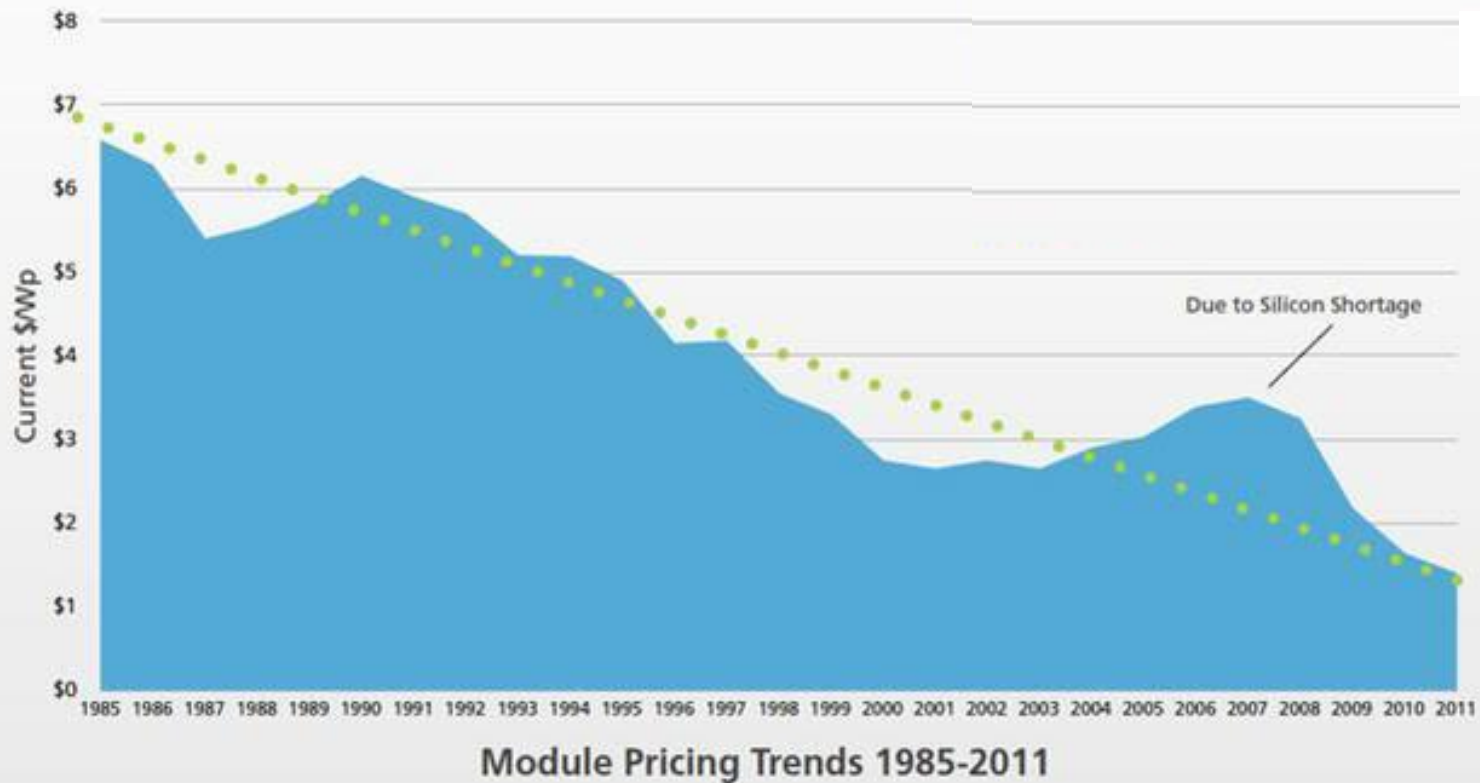
Source: PV Status report 2013





Kilde: <http://www.posterus.sk/?p=1247>

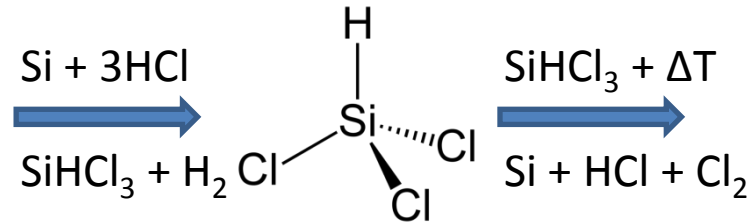
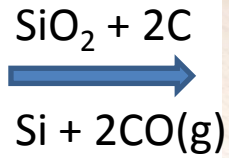
Solar Industry Growth has Produced Steadily Falling Prices



Sources: 1976-1985 data from IPCC, Final Plenary, Special Report Renewable Energy Sources (SRREN), May 2011; 1985-2010 data from Paula Mints, Principal Analyst, Solar Services Program, Navigant; 2011 numbers based on current market data

<http://sambridge.wordpress.com/2011/10/05/solar-panels-have-never-been-cheaper/>

Pris



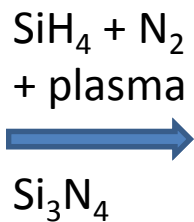
KOH ets
Matt



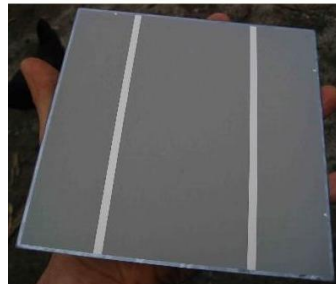
P-doping
p-n junction



Saging
Wafers

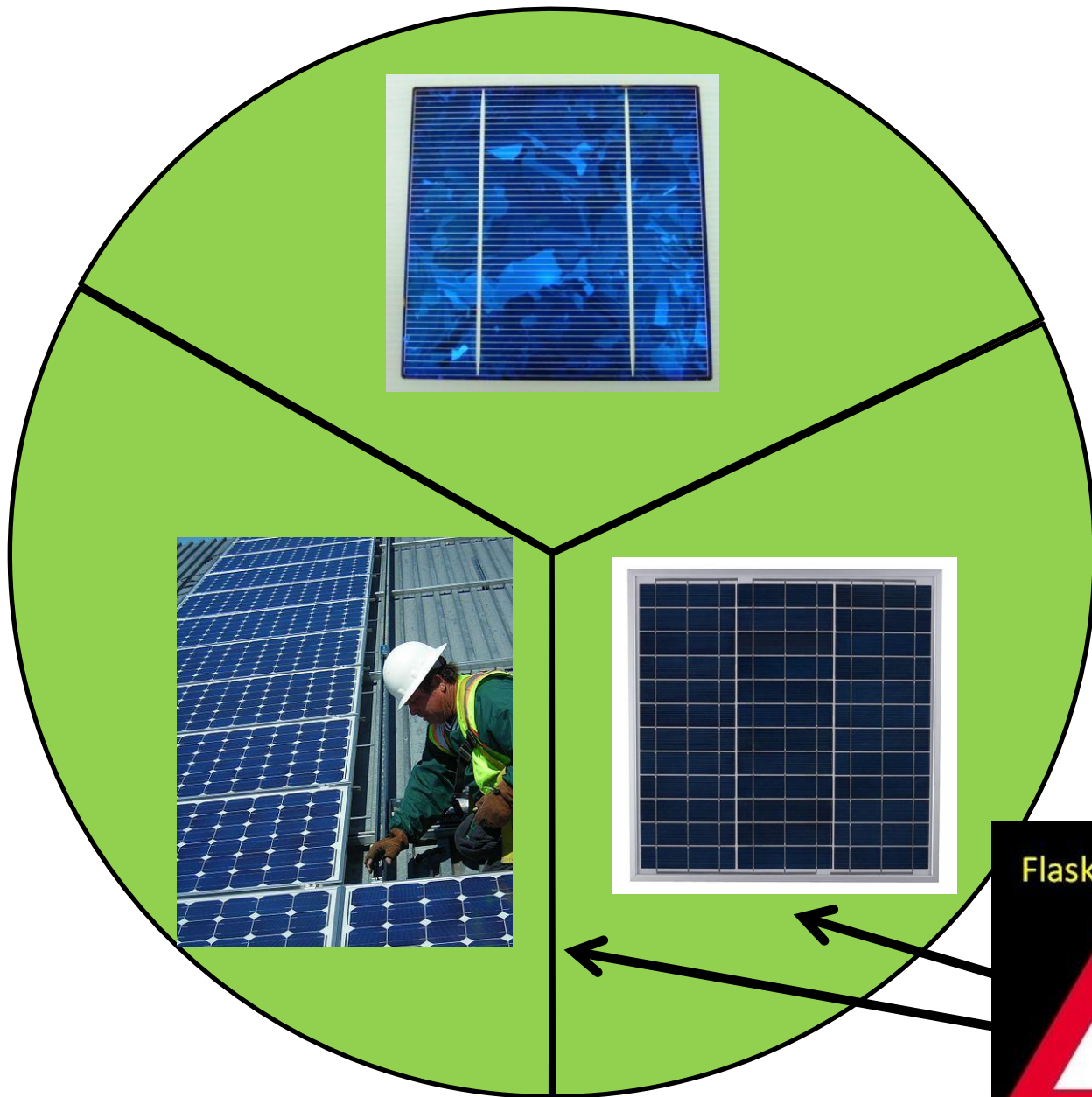


Al + ΔT
Bak-
kontakt



Ag + ΔT
Front-
kontakt

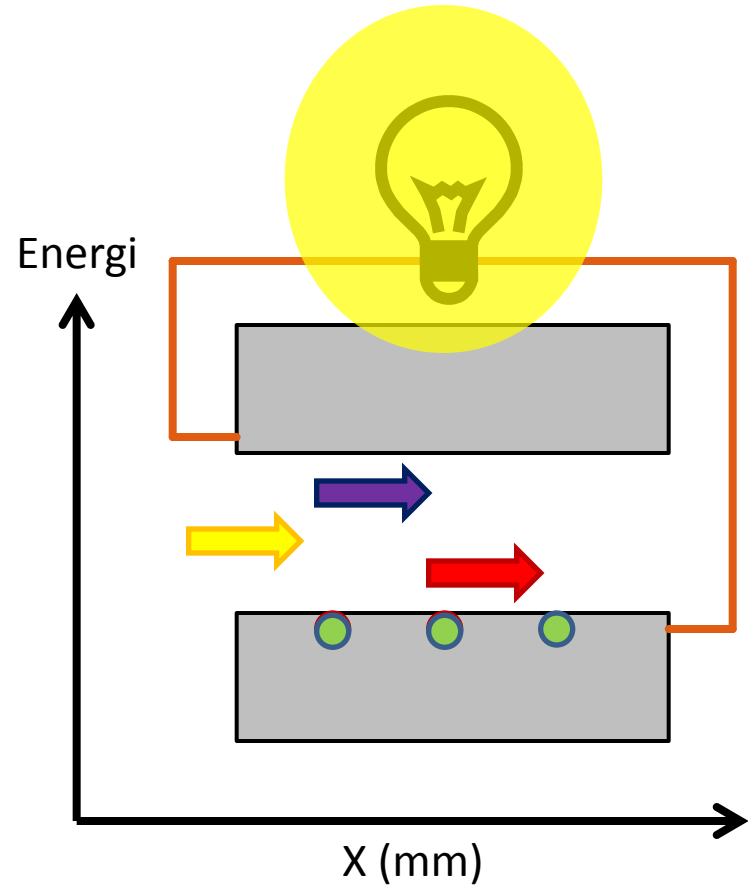
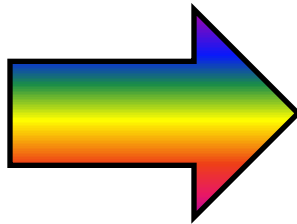




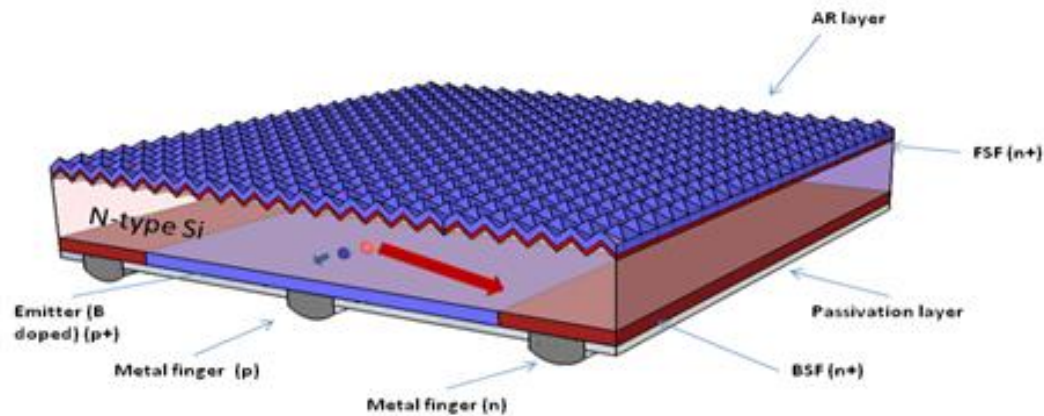
Silicon, for good or worse



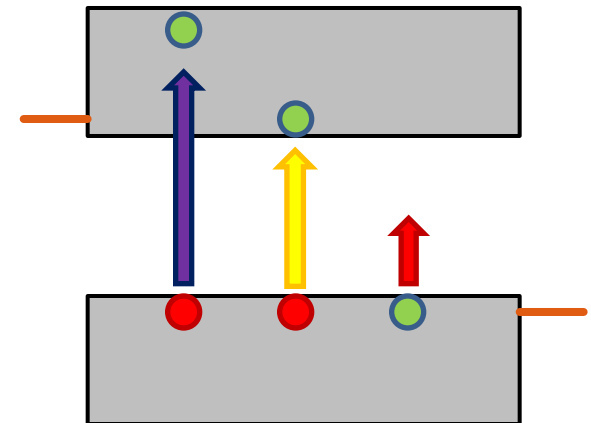
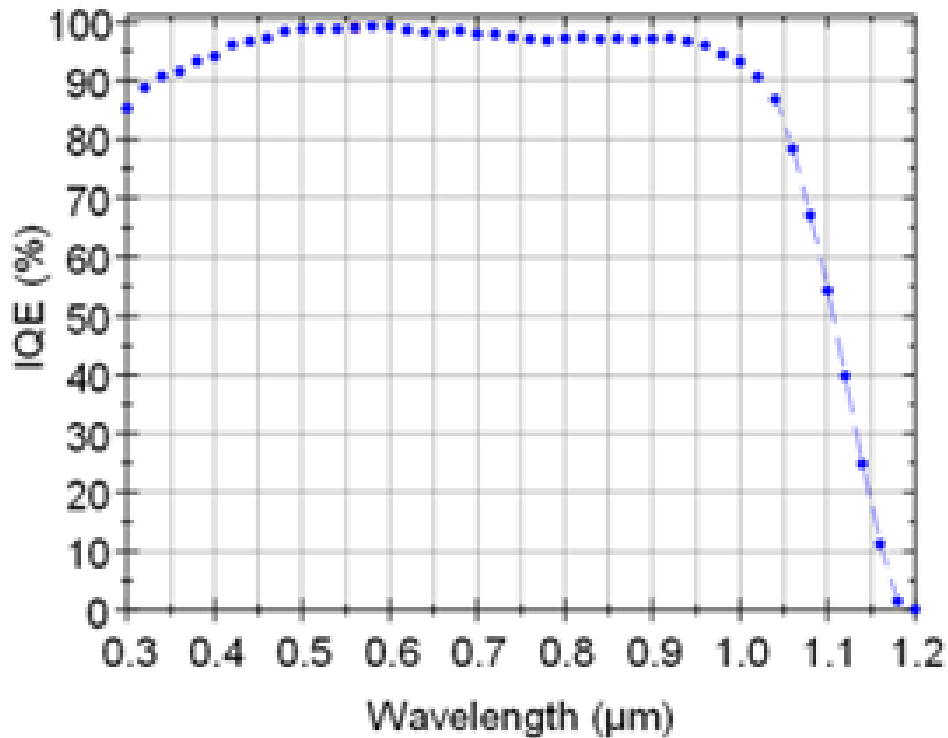
Silicon, for good or worse



Hvor går energien?



$$\eta = 19,6 \%$$

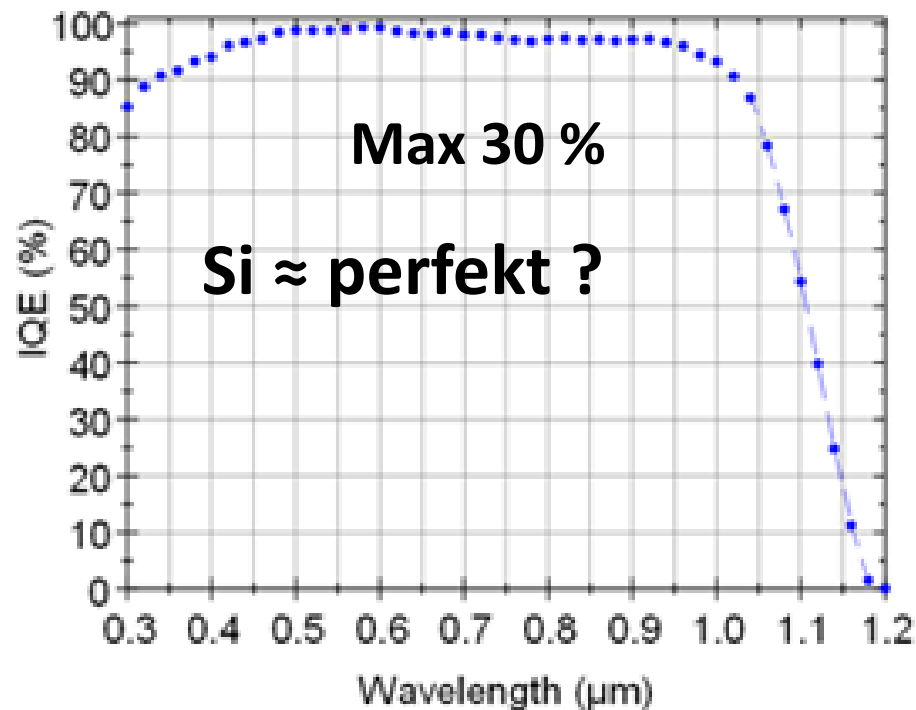
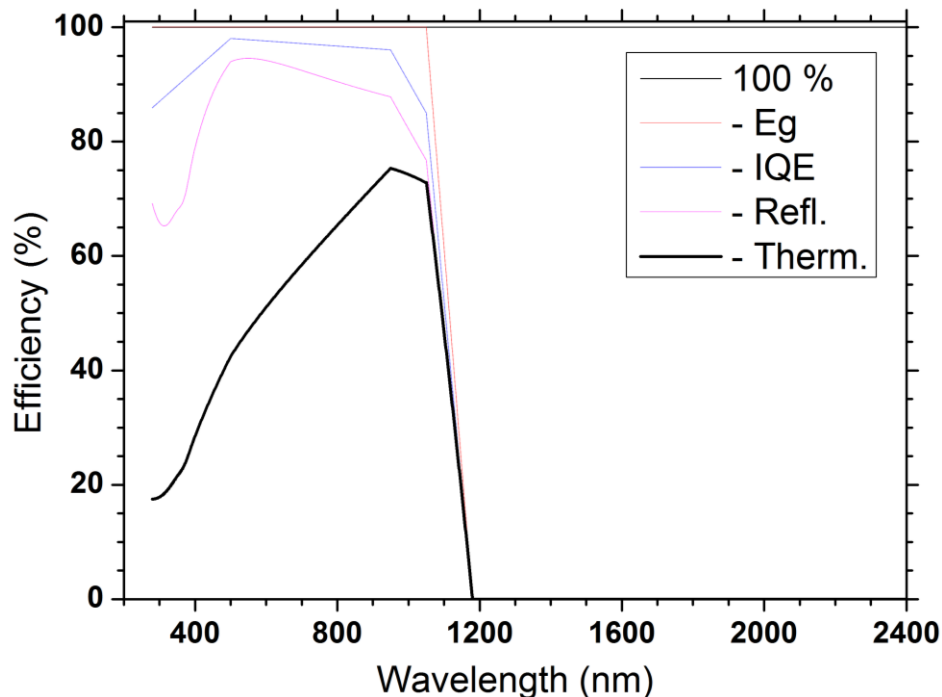
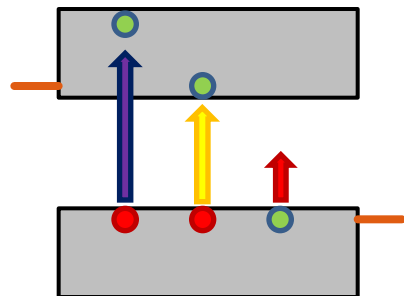


Hvor går energien



19,6 %

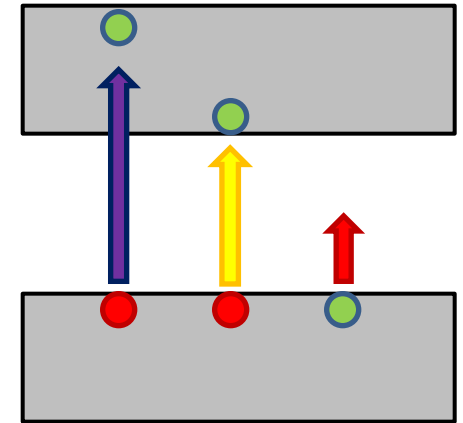
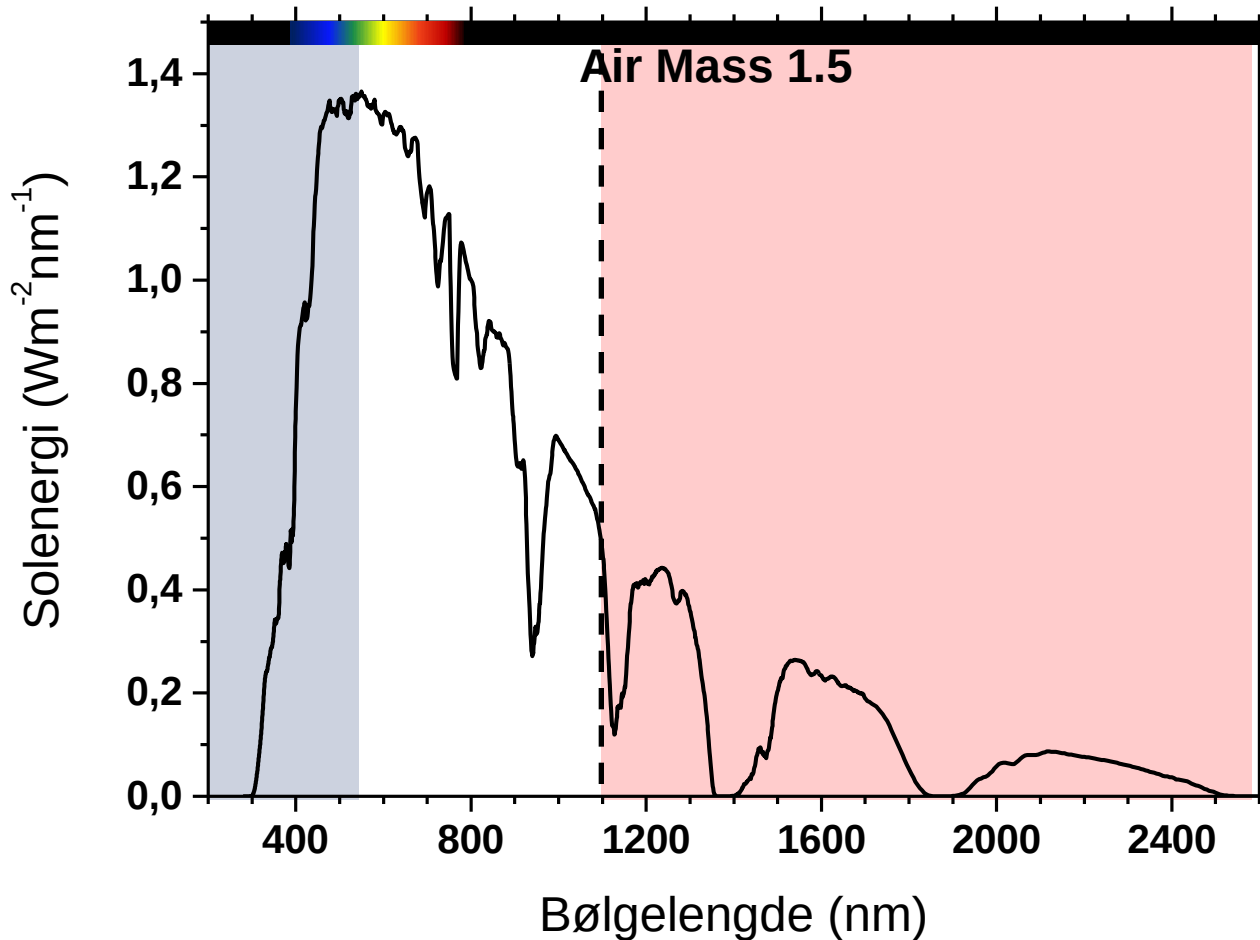
1. Båndgap
2. IQE $\neq$ 100 %
3. Refleksjon
4. Thermalization
5. Ikke- λ tap



Max 30 %
Si $\approx$ perfekt ?

Silicon, for good or worse

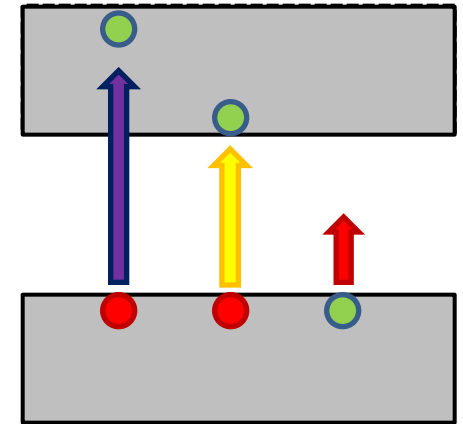
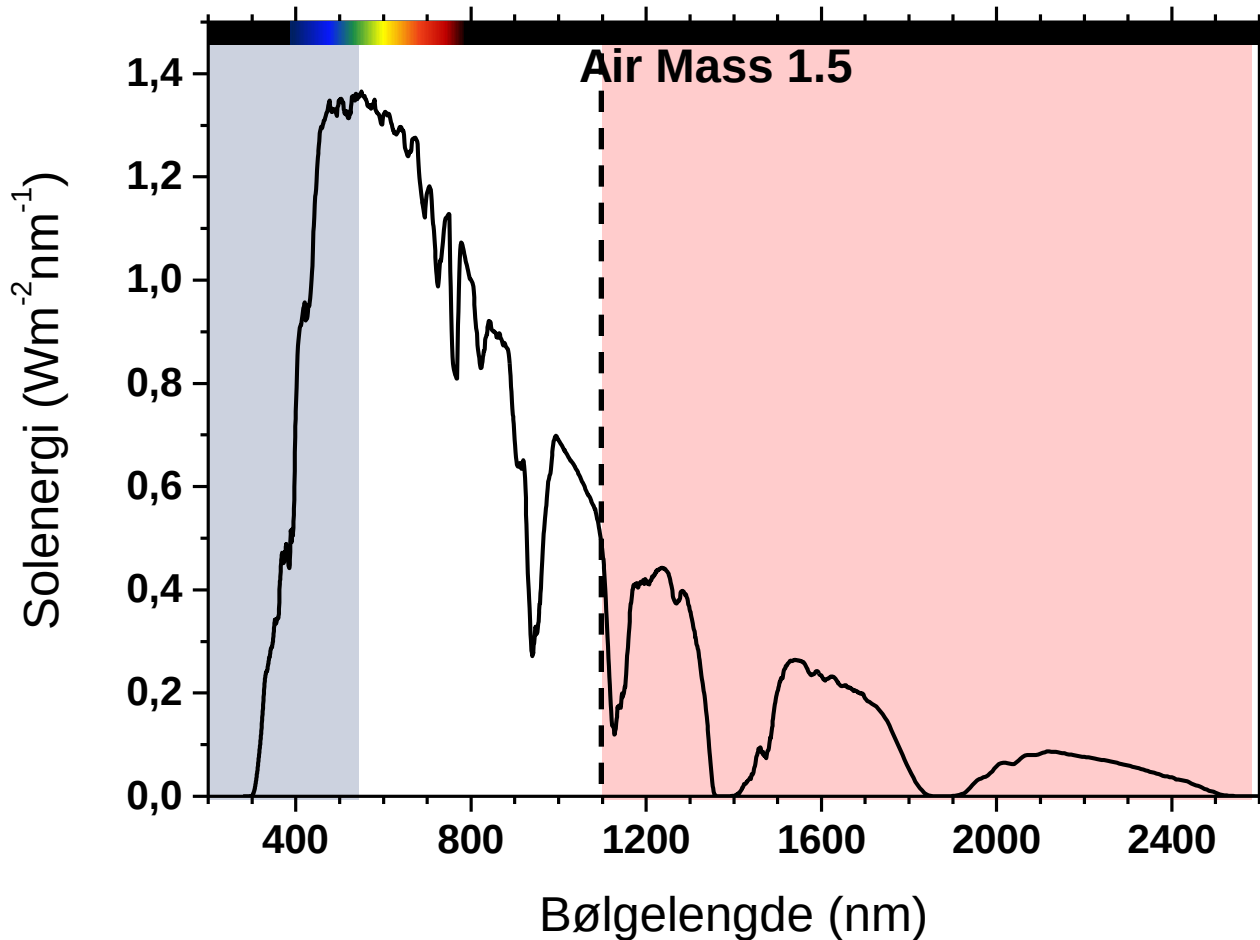
Si: 1.1 eV = 1100 nm



Silicon, for good or worse

GaAs: 1.4 eV = 890 nm

Si: 1.1 eV = 1100 nm

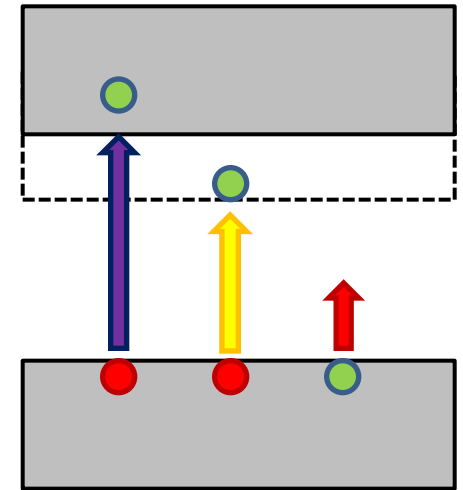
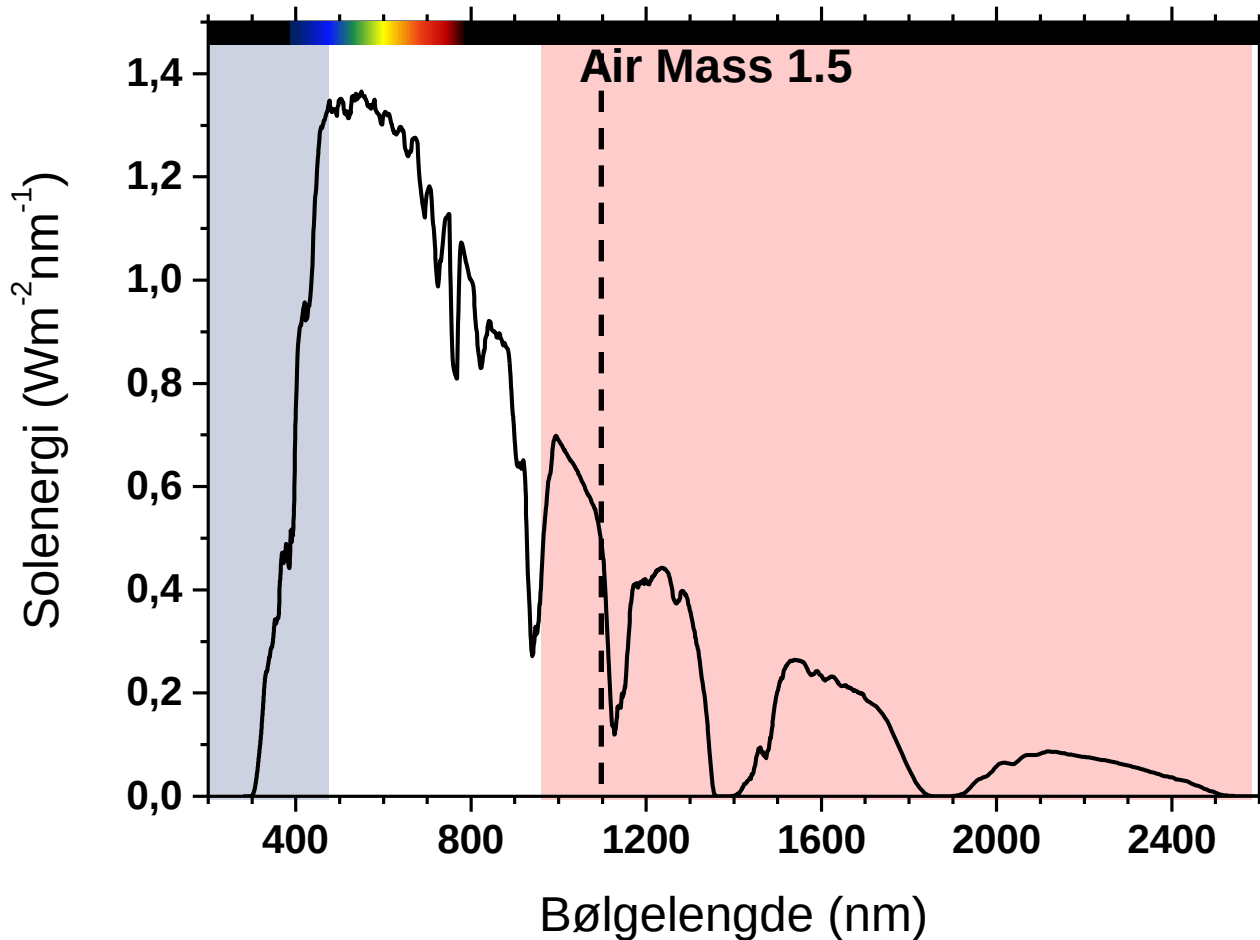


Silicon, for good or worse

GaAs: 1.4 eV = 890 nm

Si: 1.1 eV = 1100 nm

Ge: 0.7 eV = 1800 nm



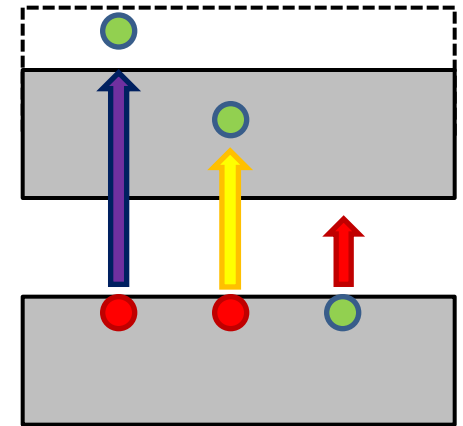
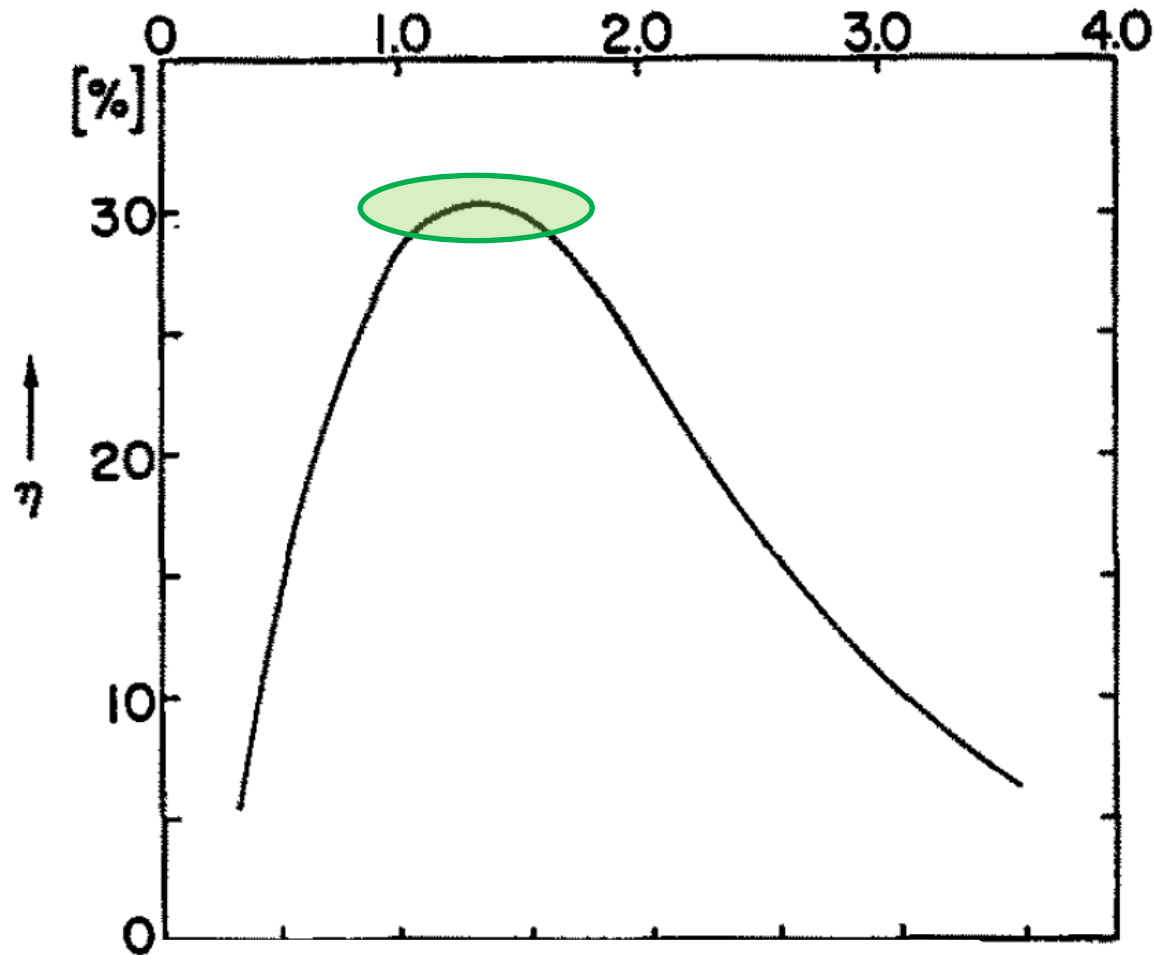
Silicon, for good or worse

GaAs: 1.4 eV = 890 nm

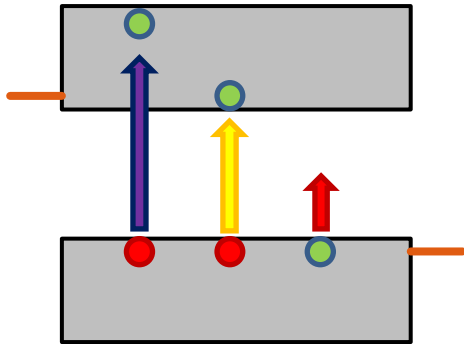
Si: 1.1 eV = 1100 nm

Ge: 0.7 eV = 1800 nm

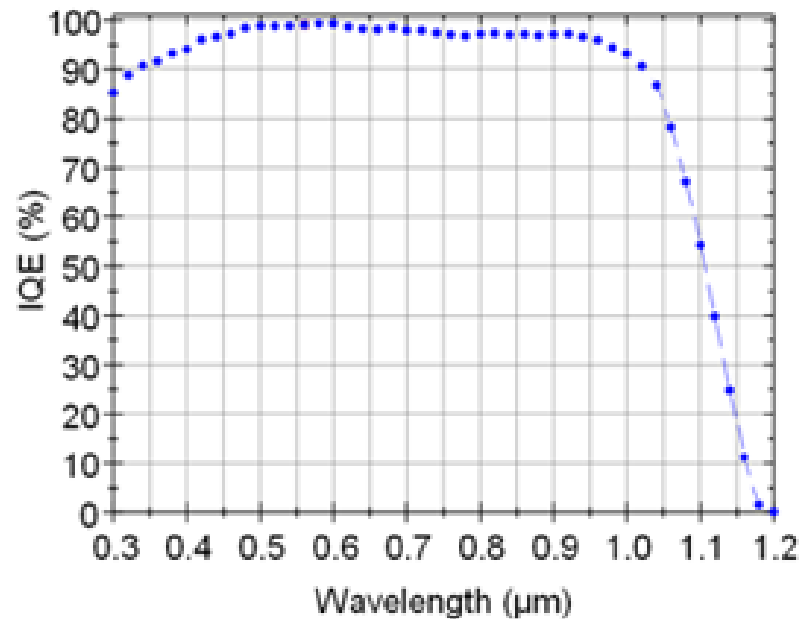
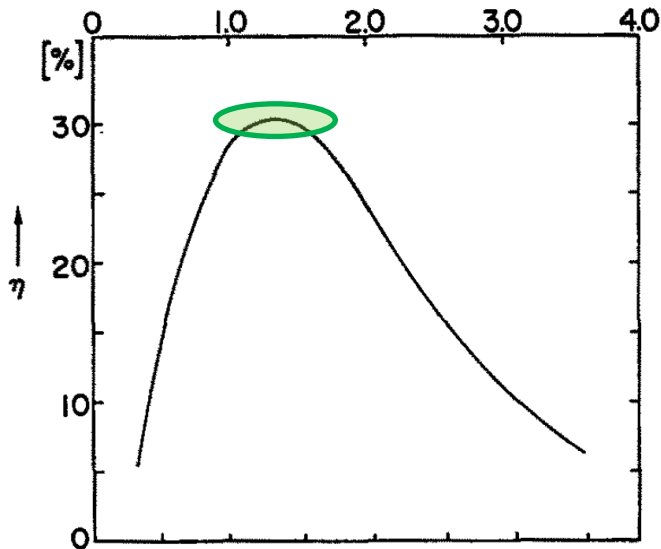
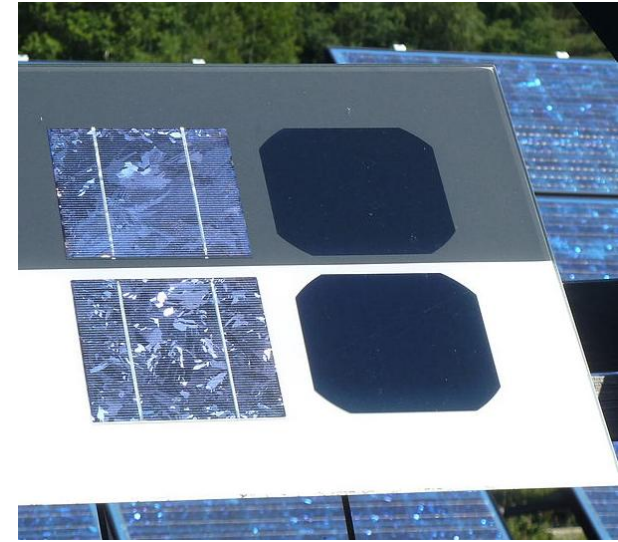
Beste Si: 27.6 % (2005)



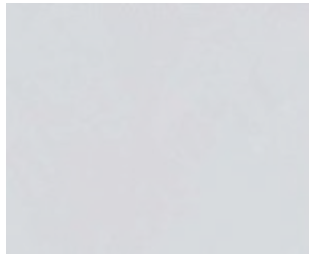
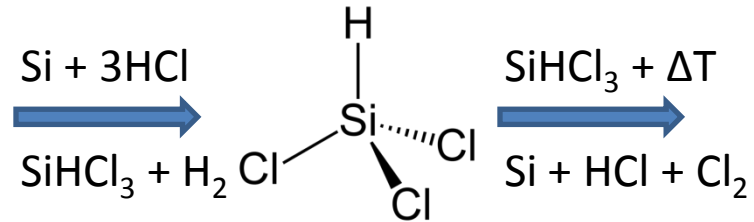
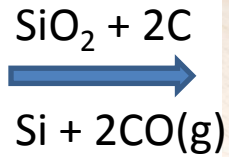
Veien videre? Nye materialer?



Billig 15 %
vs
Dyr 27.6 %



Pris ca. 10 kr



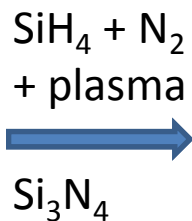
KOH ets
Matt



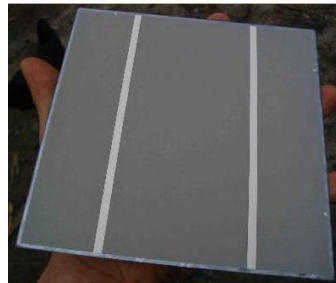
P-doping
p-n junction



Saging
Wafers



Al + ΔT
Bak-
kontakt



Ag + ΔT
Front-
kontakt



CuInGaSe (CIGS) 22.8 %

Beste Si: 27.6 %

CuZnSnS (CZTS) 11.1 %

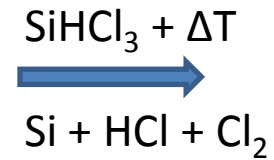
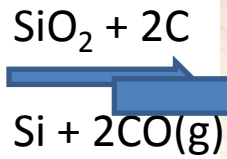
CdTe 19.6 %

Amorf Si 13.4 %

Polymer 11.9 %

	I	II	CuZnSnS (CZTS) 11.1 %										III	IV	V	VI	VII	VIII	
	CdTe 19.6 %																		
	Amorf Si 13.4 %																		
	Polymer 11.9 %																		
1	1 H																		2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo	
8	119 Uun																		
	* Lanthanides		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		
	** Actinides		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		

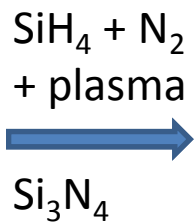
Pris ca. 10 kr



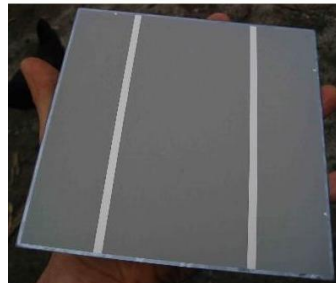
KOH ets
Matt



Saging
Wafers



Al + ΔT
Bak-
kontakt



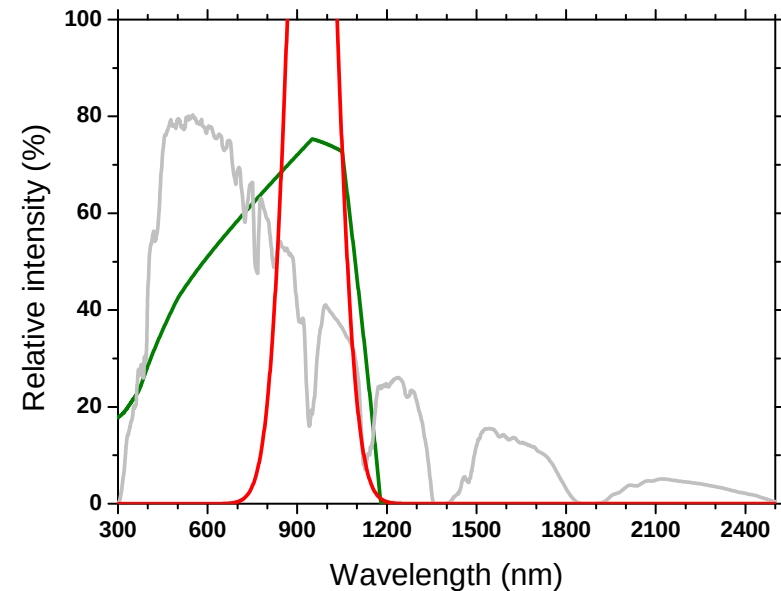
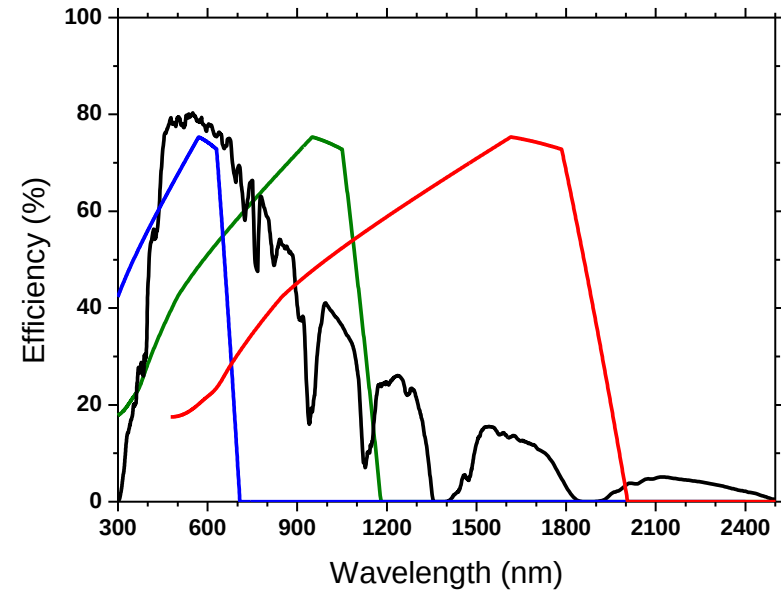
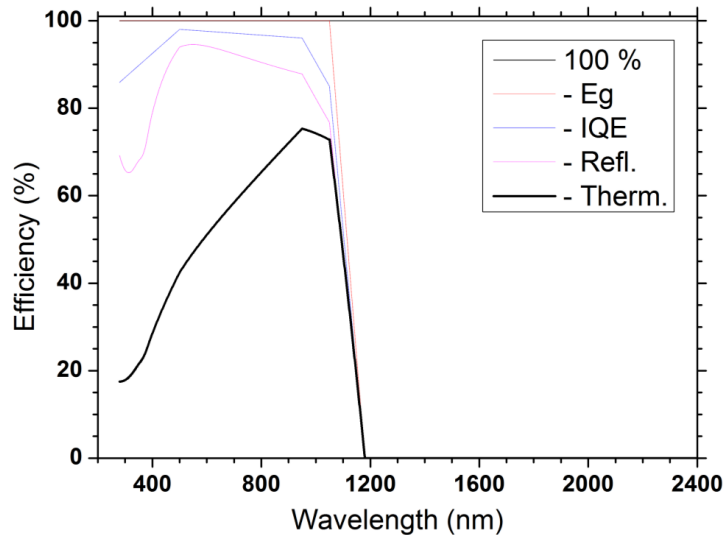
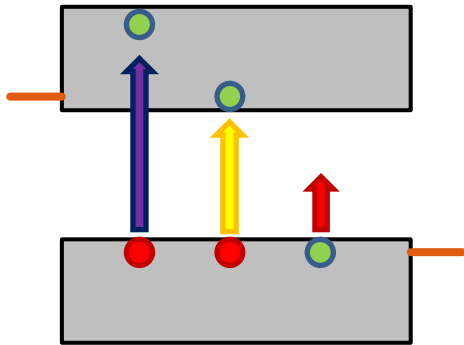
Ag + ΔT
Front-
kontakt





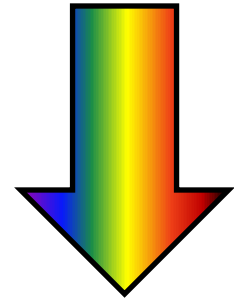
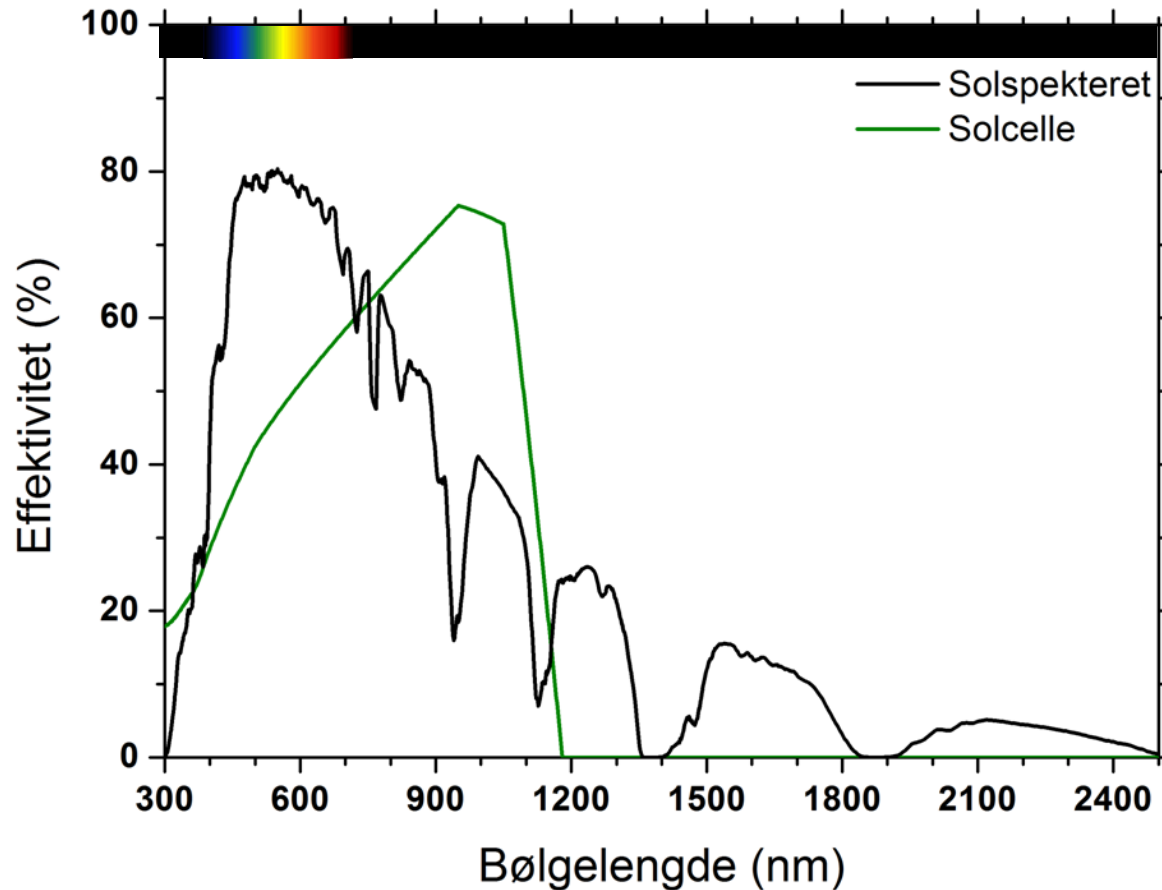


Veien videre? Nye materialer?



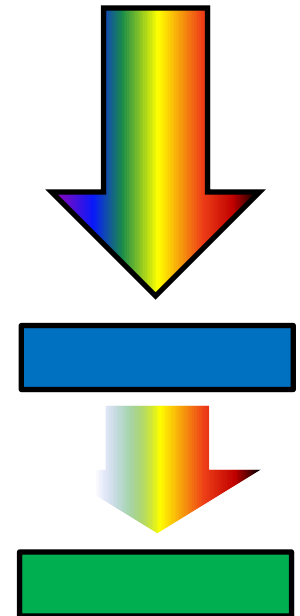
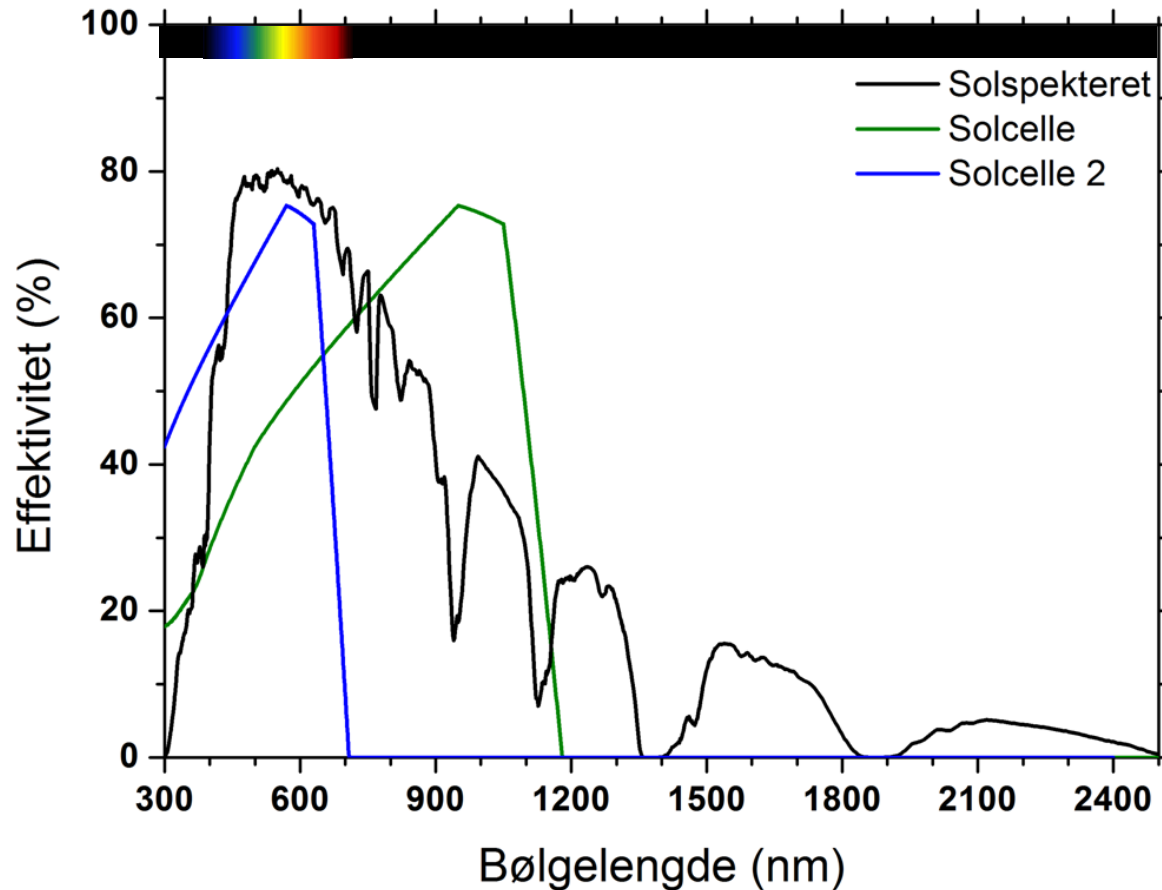
Multi-junction solceller

GaAs, III-V



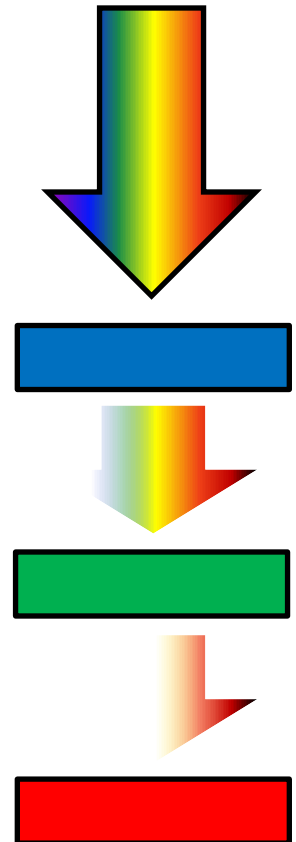
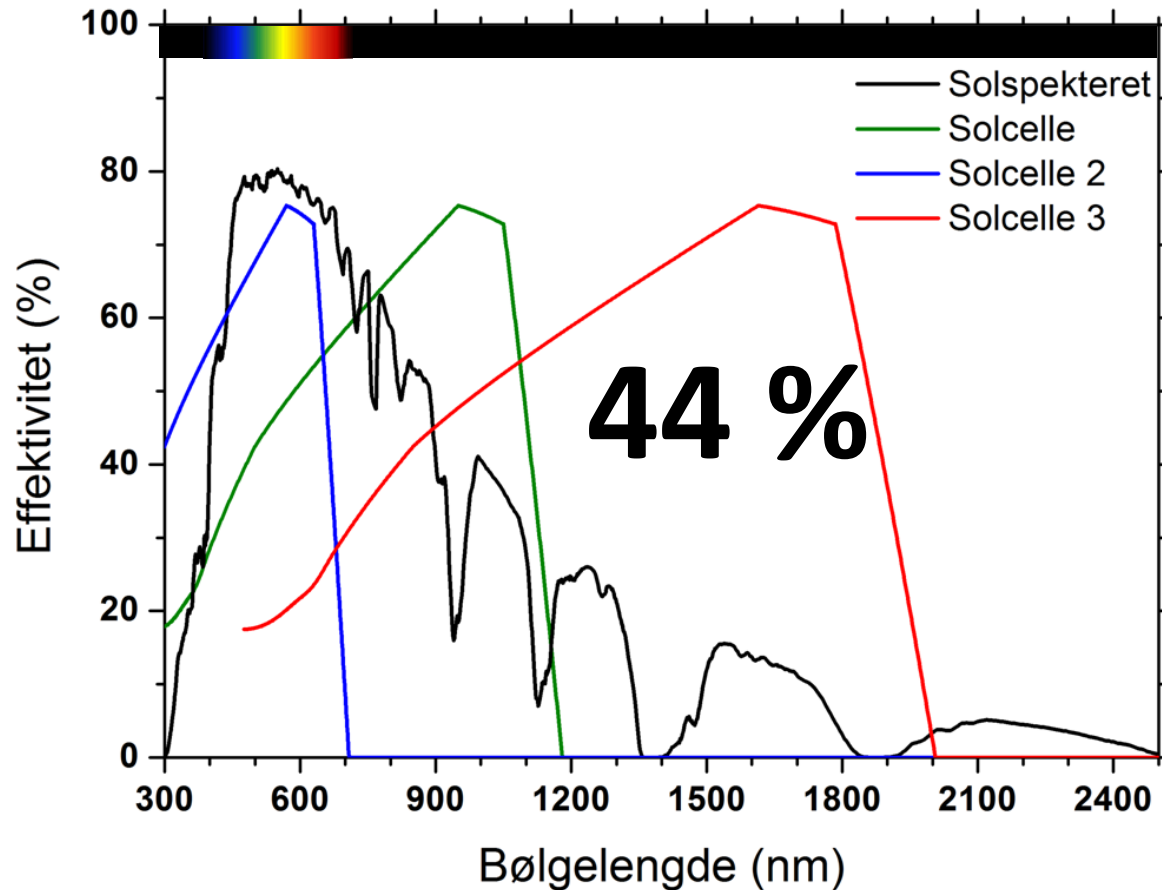
Multi-junction solceller

GaAs, III-V



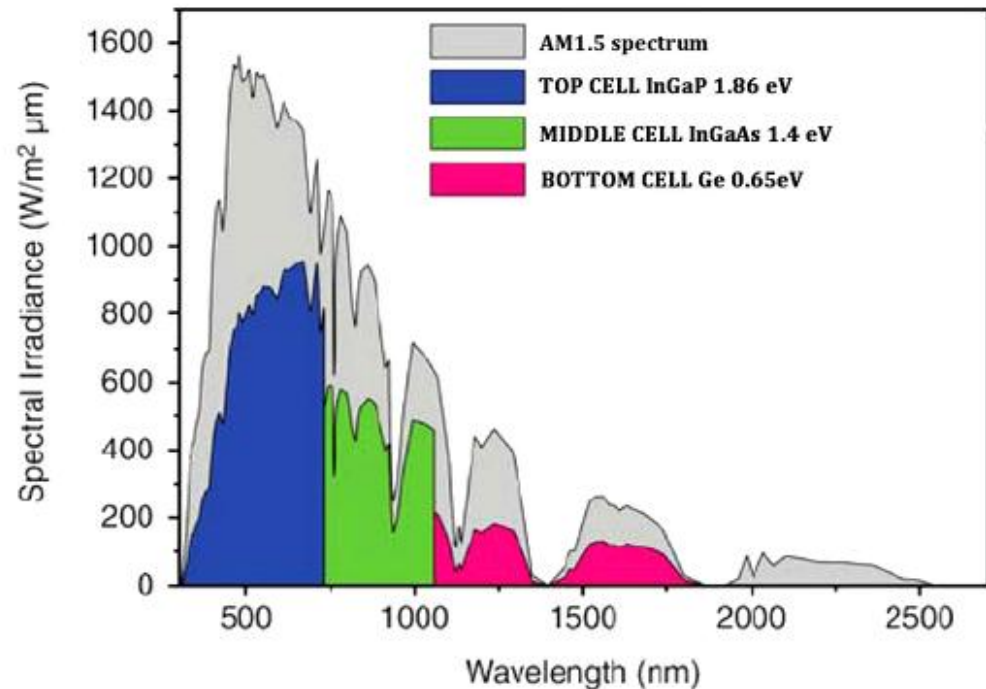
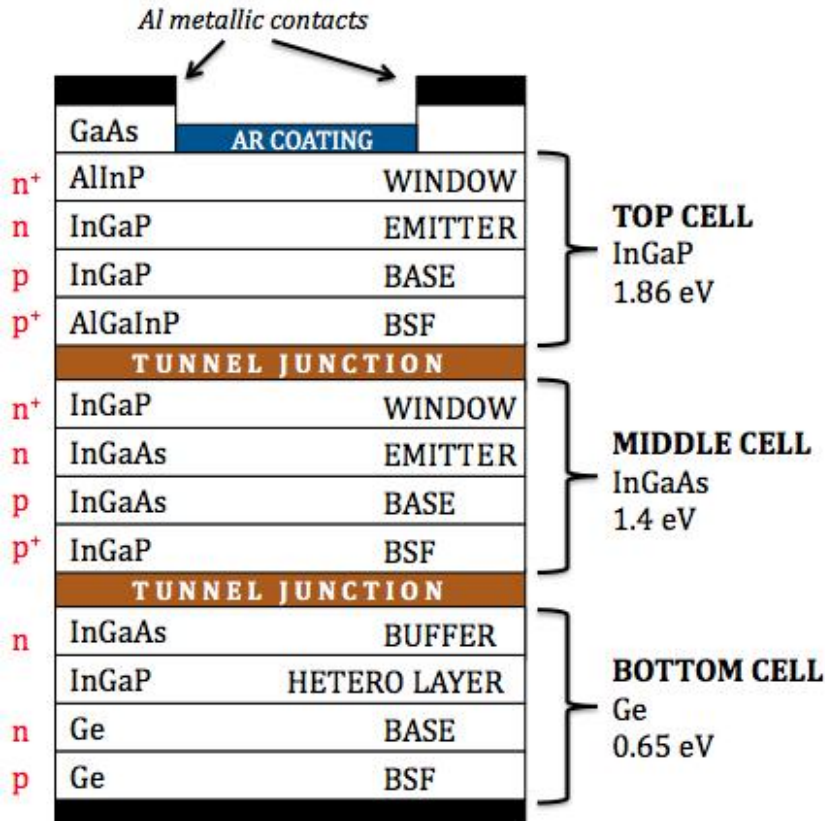
Multi-junction solceller

GaAs, III-V



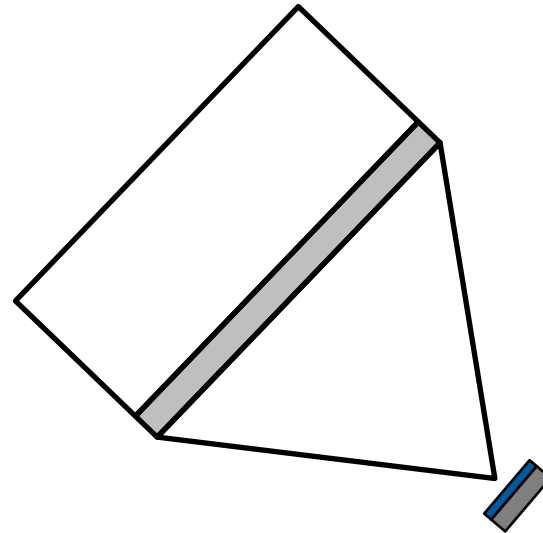
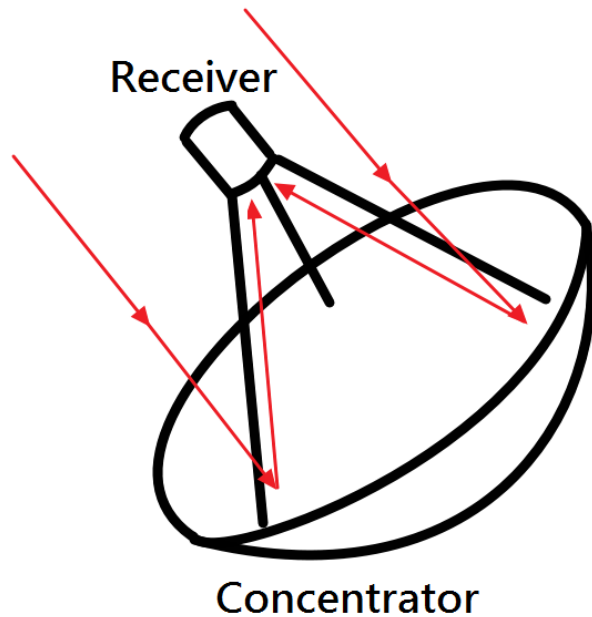
Multi-junction solceller

GaAs, III-V



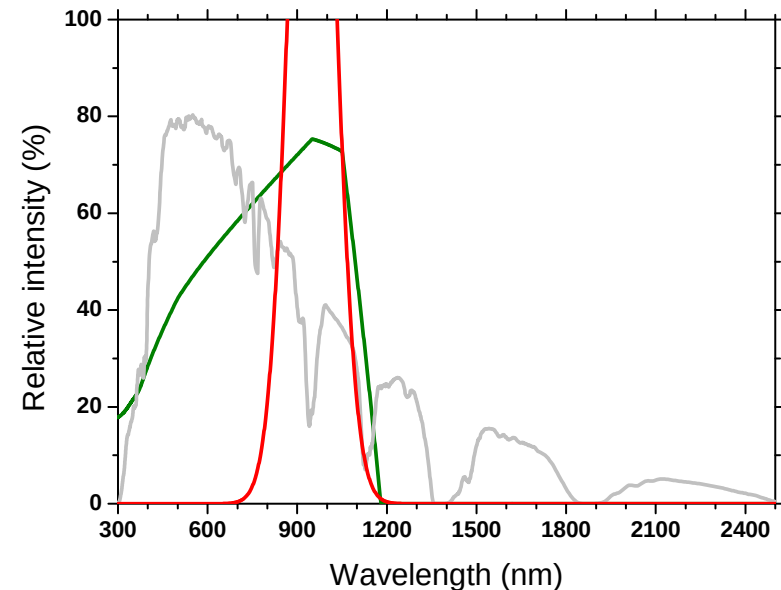
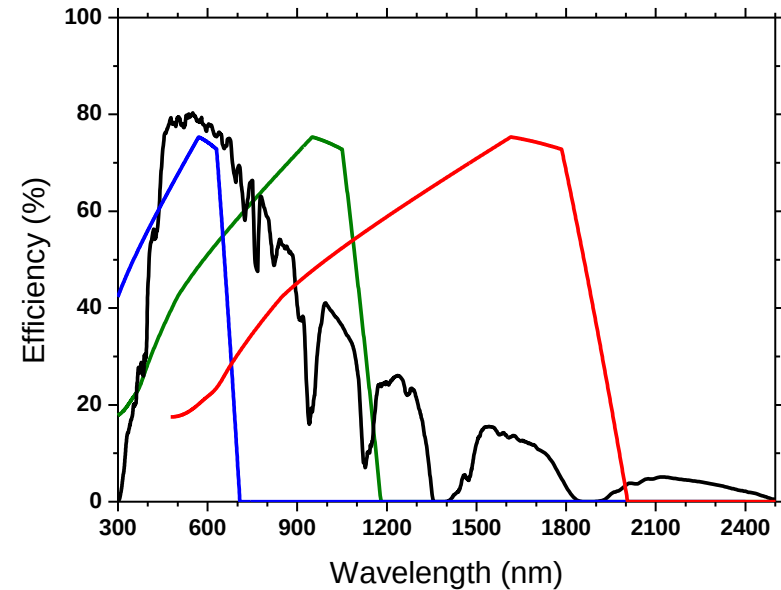
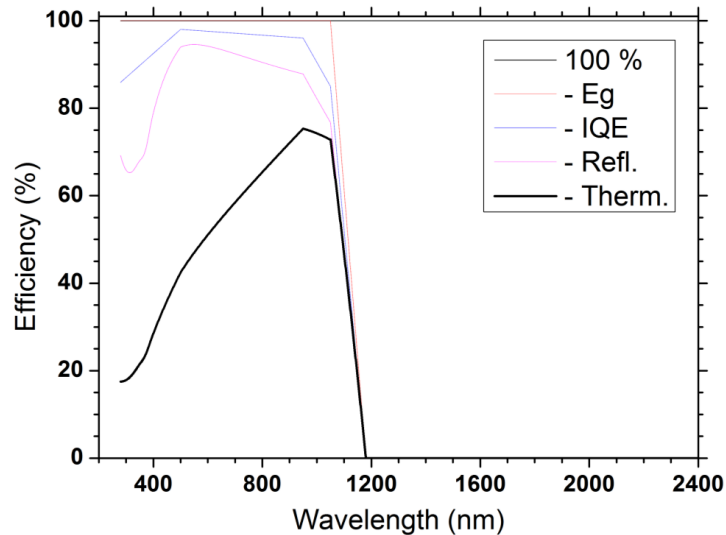
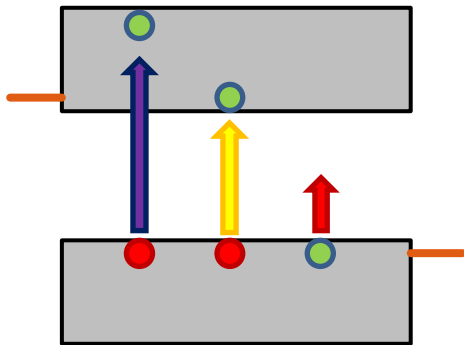
Multi-junction solceller

GaAs, III-V

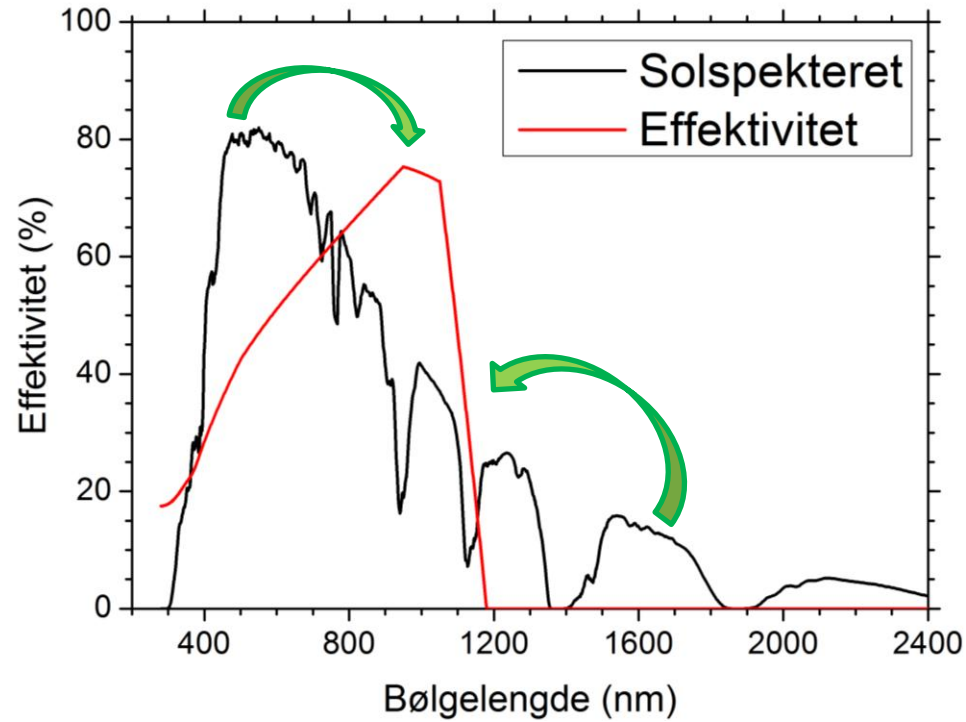




Veien videre? Nye materialer?

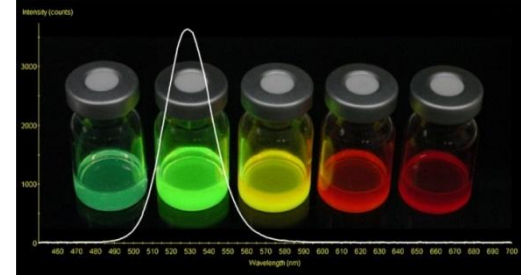


Tilpasse sollyset

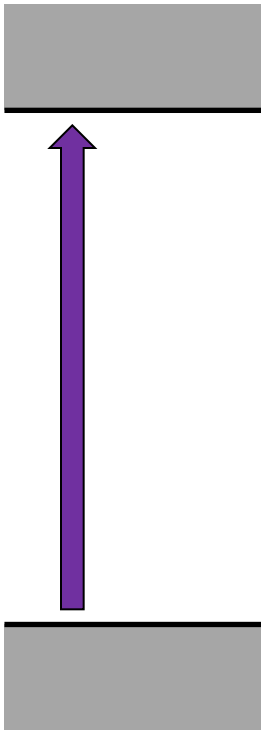




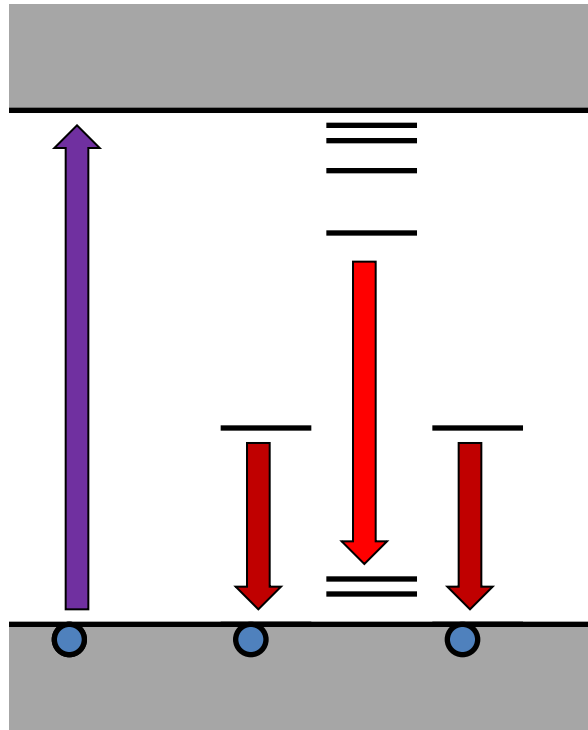
Tilpasse sollyset



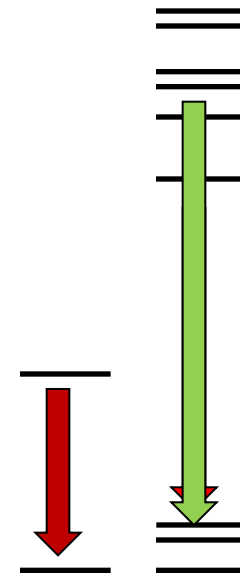
Absorber



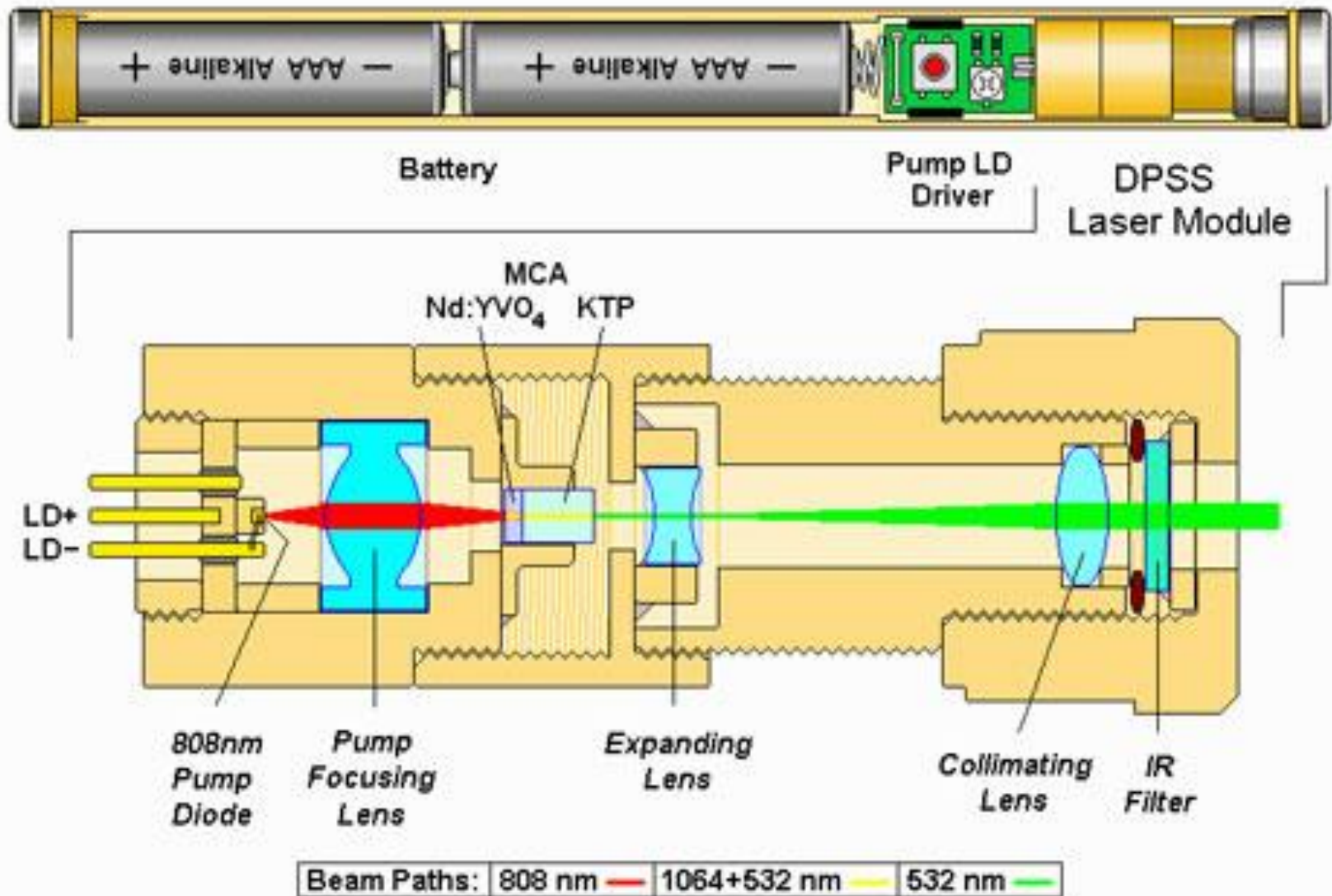
UV → 2NIR



Emitter



Tilpasse sollyset



Tilpasse sollyset

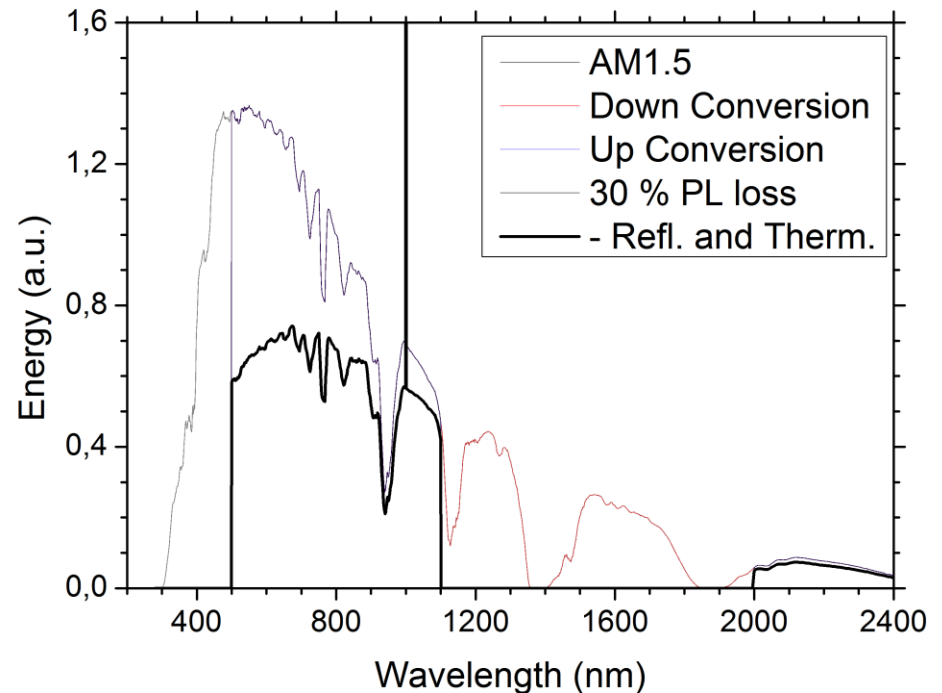
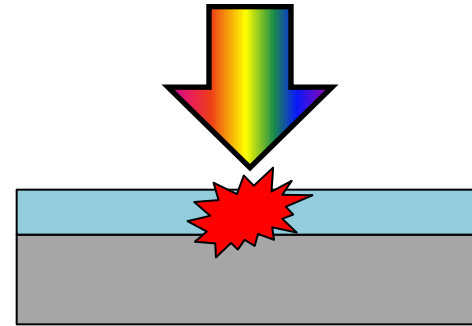
Down conversion
(1→2)

Up conversion (2→1)

Assumptions:

- 100 % Absorption
- 194 % Down conversion¹
- 40 % Up conversion²
- 30 % Luminescence loss

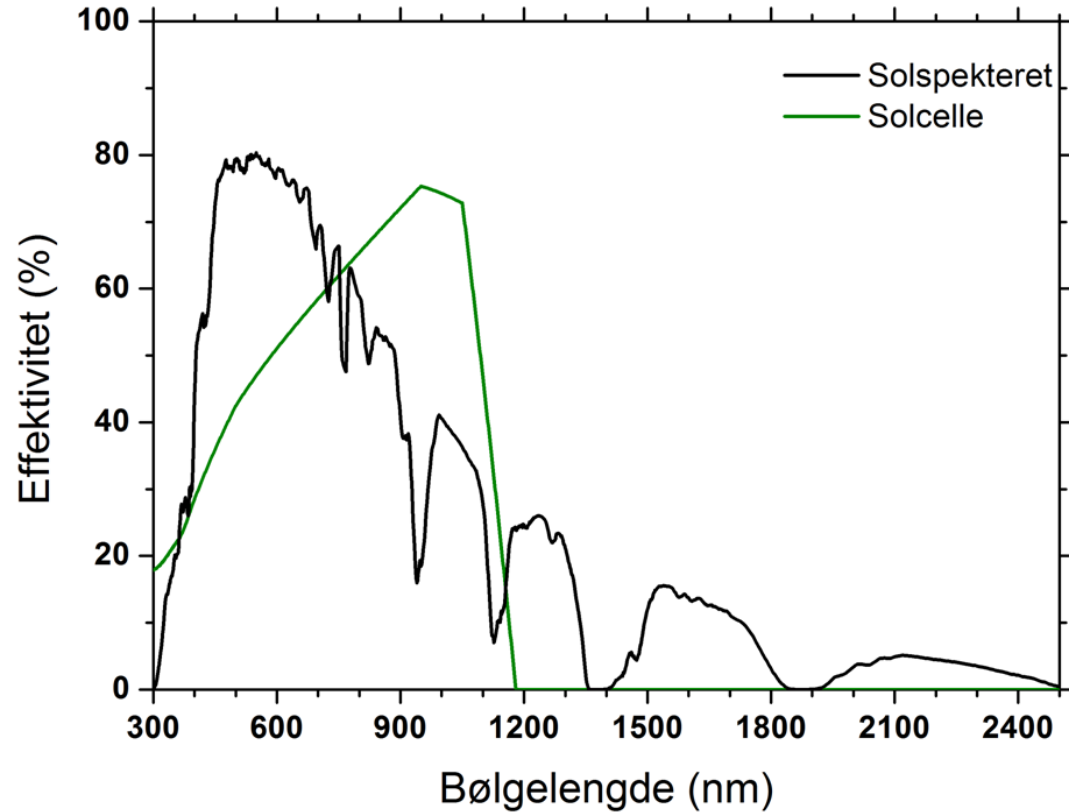
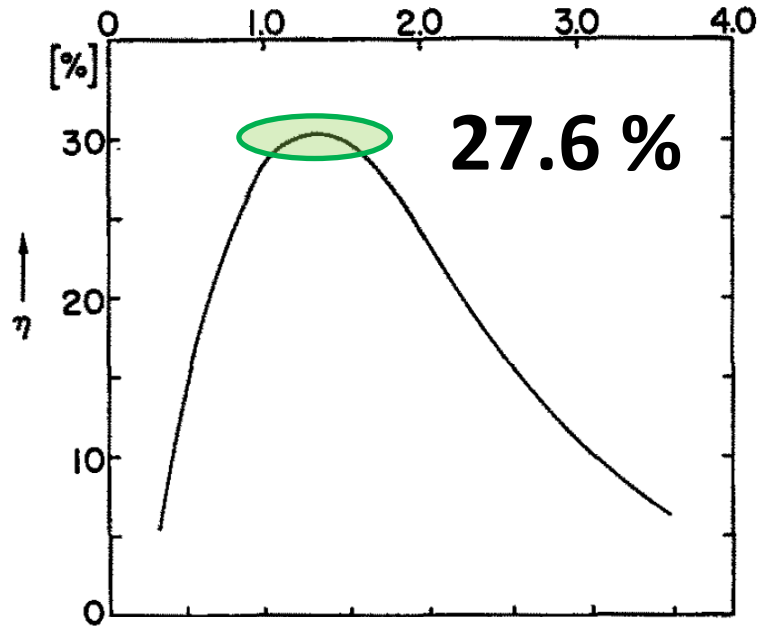
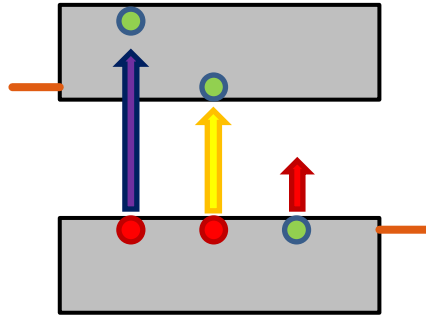
$\eta = 19.6 \% \rightarrow 22.3 \% (24.7 \%)$



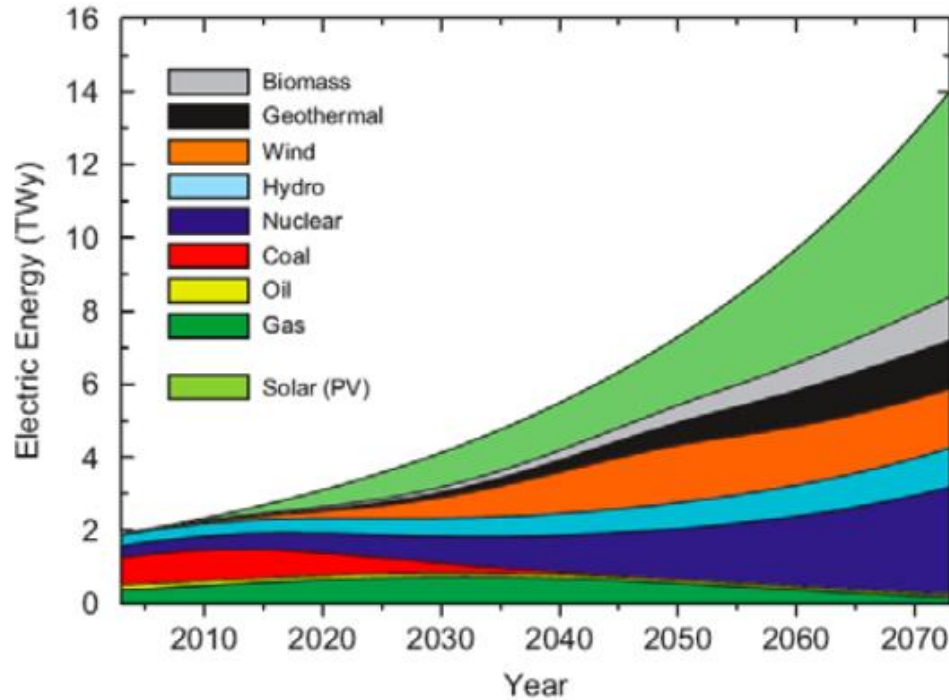
¹ Bo Liu *et al.*, **Visible quantum cutting in BaF₂: Gd; Eu via downconversion**, *Journal of Luminescence* **101** (2003) 155–159

² Best frequency doublers (green laser pointers) www.unitedcrystals.com

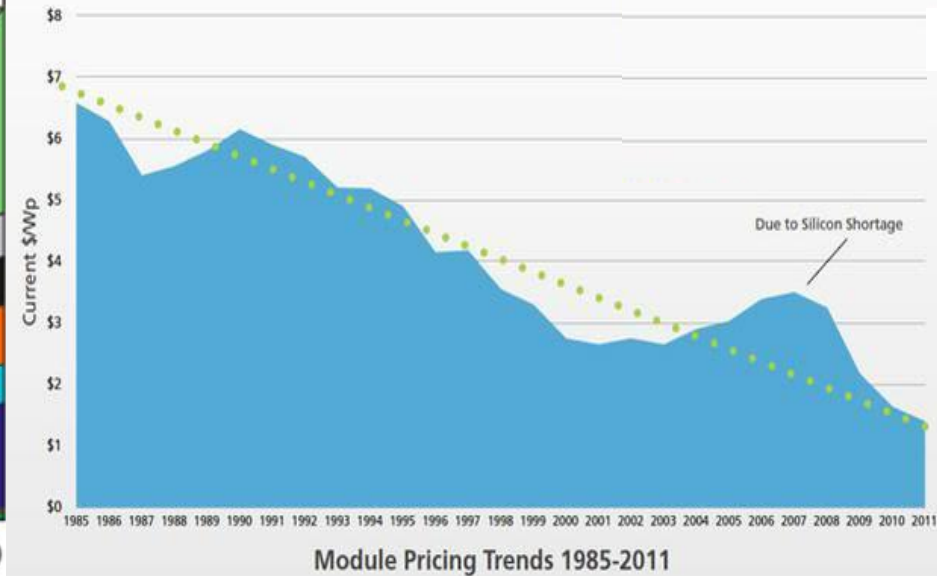
Trenger vi nye materialer?



Trenger vi nye materialer? Tja...



Solar Industry Growth has Produced Steadily Falling Prices



Sources: 1976-1985 data from IPCC, Final Plenary, Special Report Renewable Energy Sources (SRENS), May 2011; 1985-2010 data from Paula Mints, Principal Analyst, Solar Services Program, Navigant; 2011 numbers based on current market data