Photovoltaics Centre of Excellence

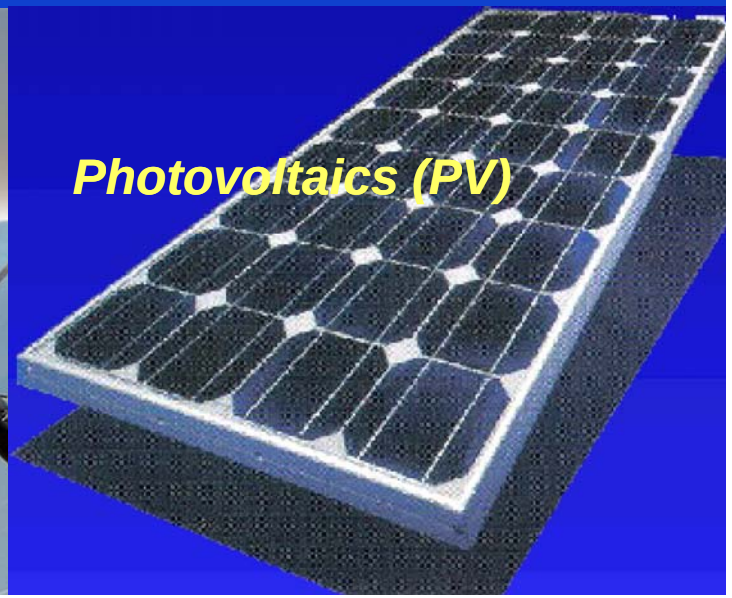
- supported by the Australian Research Council

Future of Solar Energy

Martin A. Green
University of New South Wales, Sydney

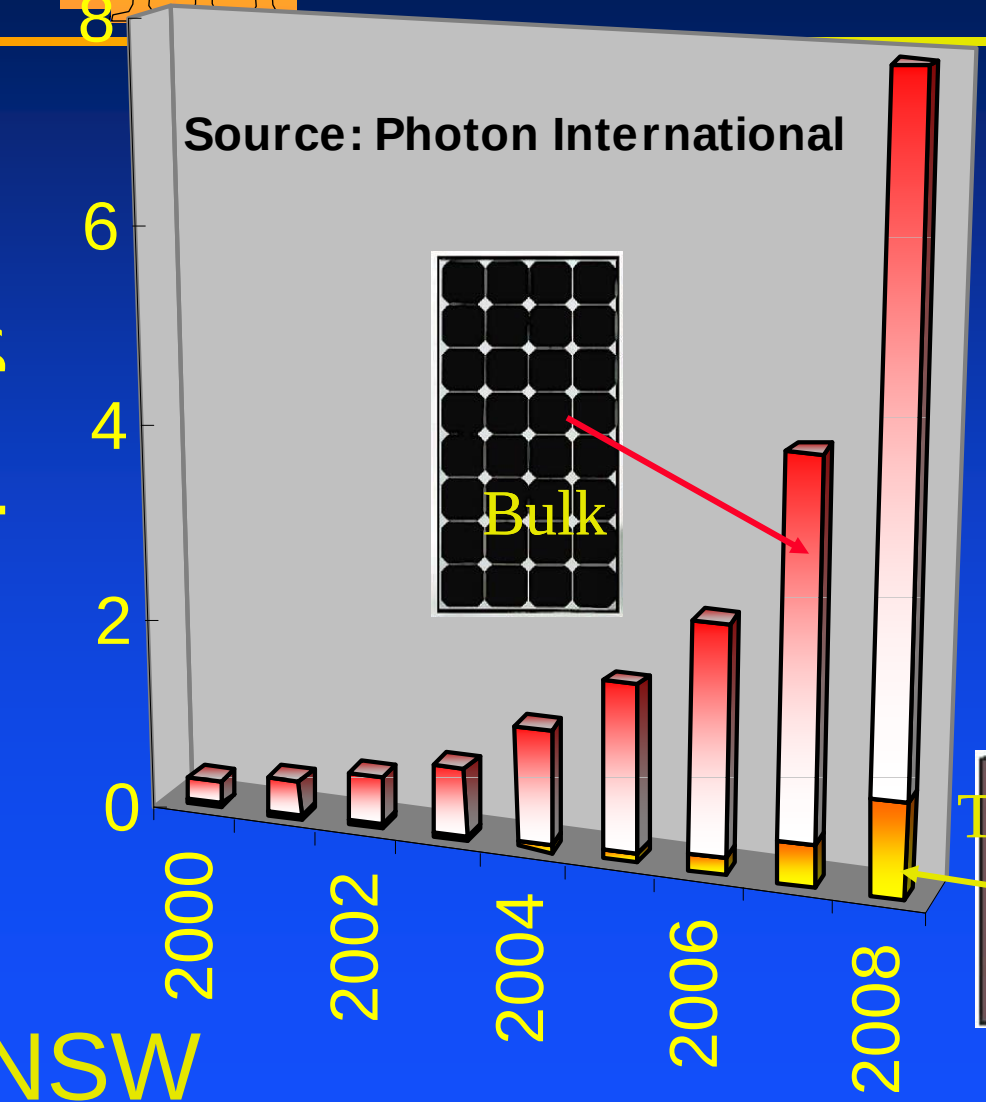
Solar water heating

Concentrating Solar Power



Photovoltaics (PV)

Solar boom



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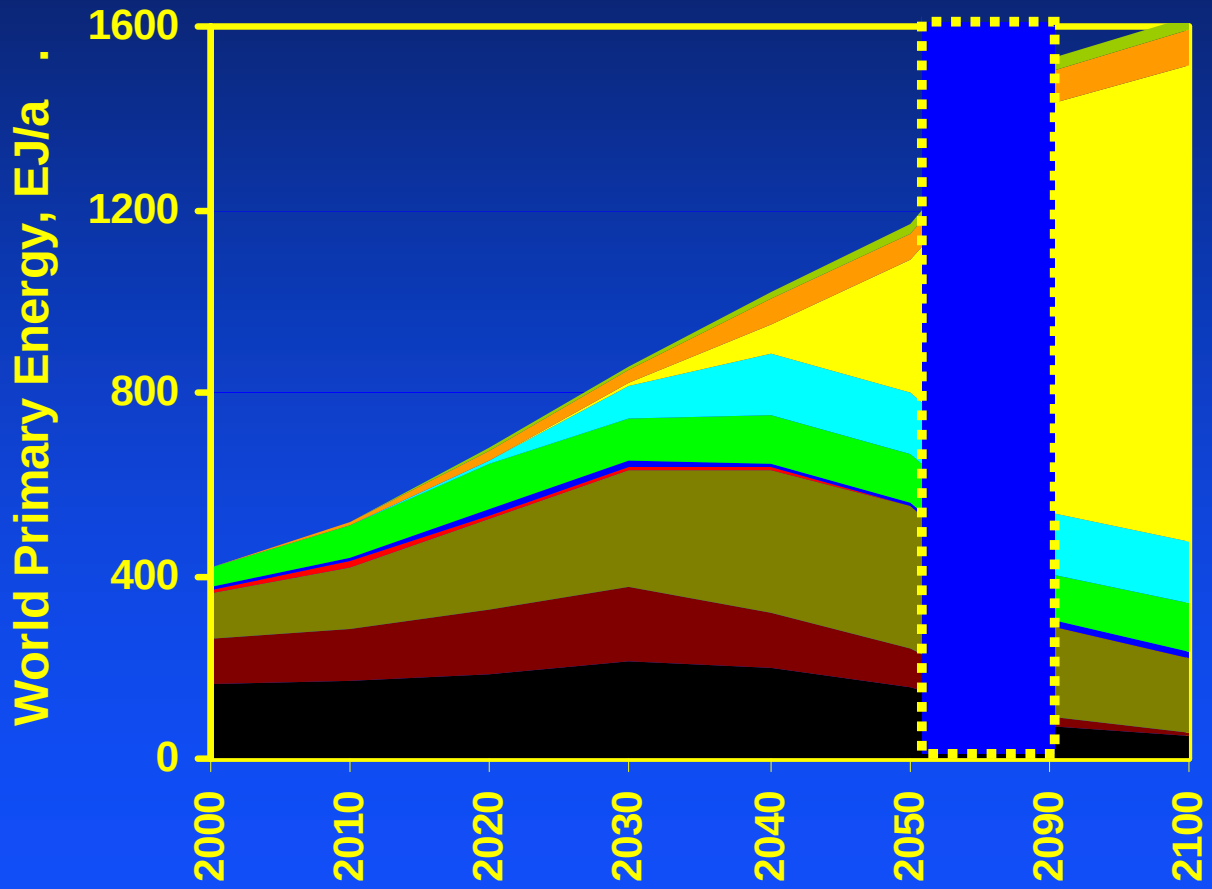
Photovo

Transition scenario

German Advisory Council on Global Change (WBGU) *2003*



- Geothermal
- Solar Heat +
- Solar Power
- Wind
- Biomass
- Hydro
- Nuclear
- Gas
- Coal
- Oil

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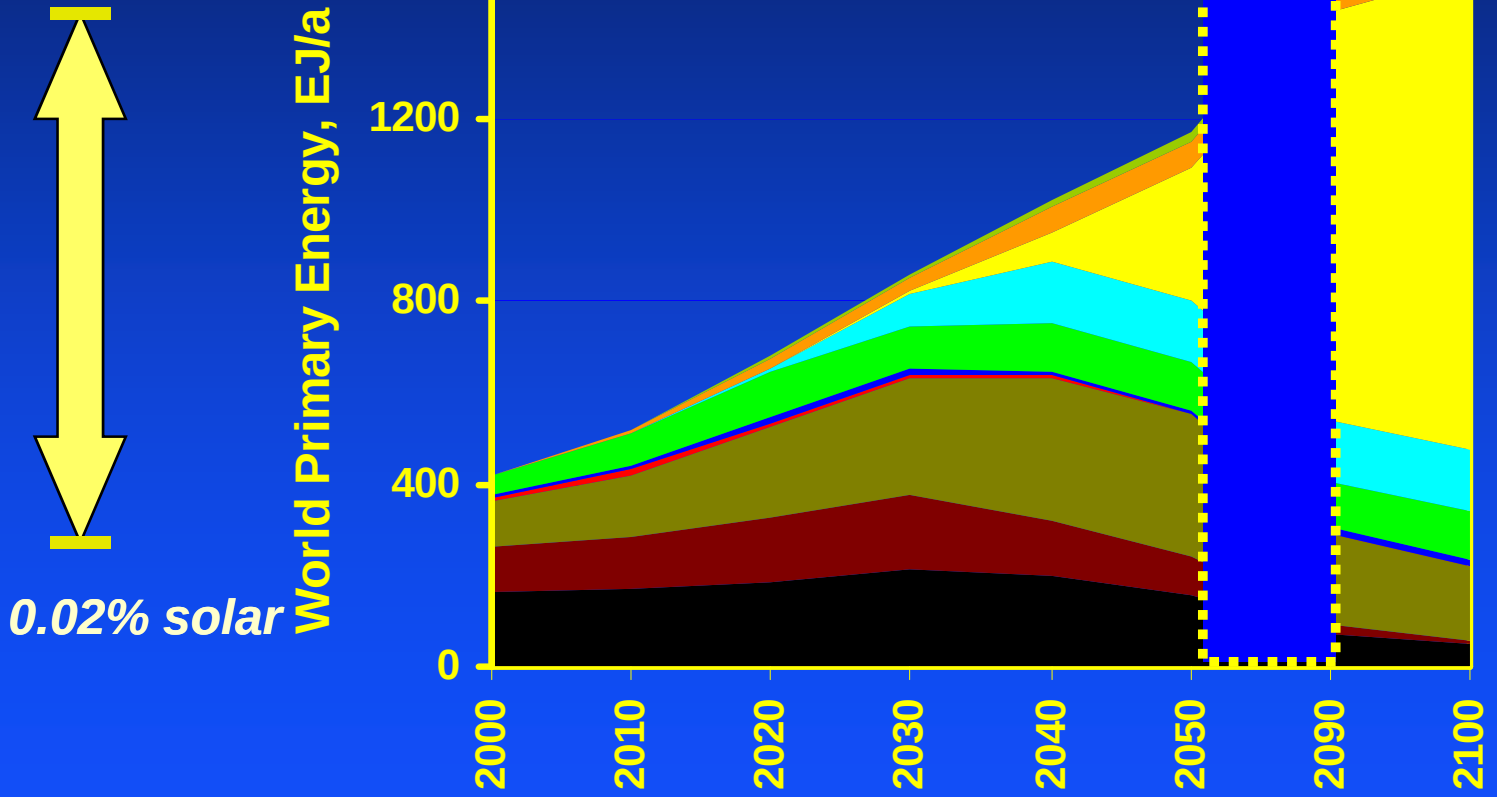
Photovoltaics - Electricity from Sunlight

Transition scenario

German Advisory Council on Global Change (WBGU) *2003*



0.02% solar

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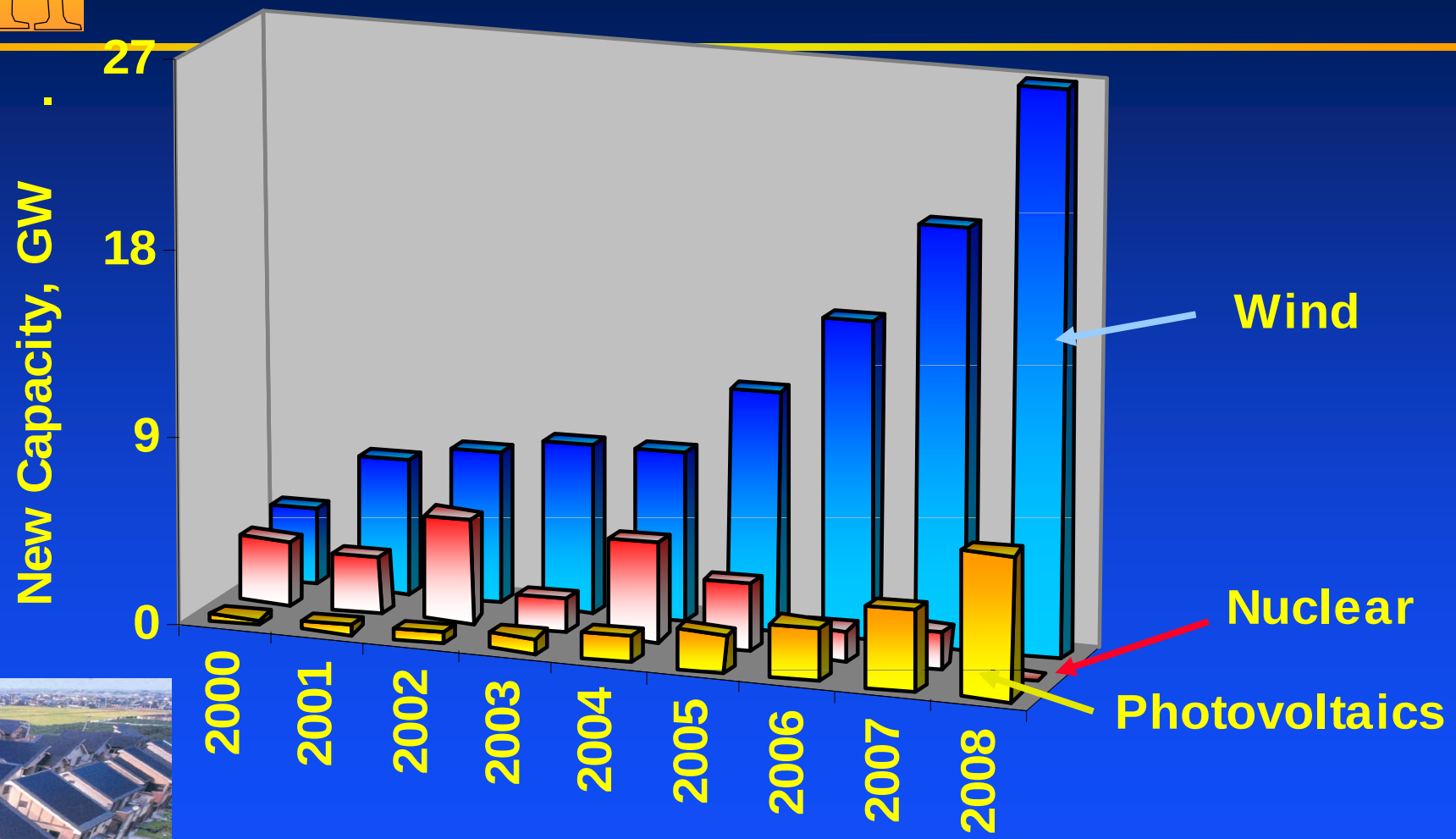
Photovoltaics - Electricity from Sunlight

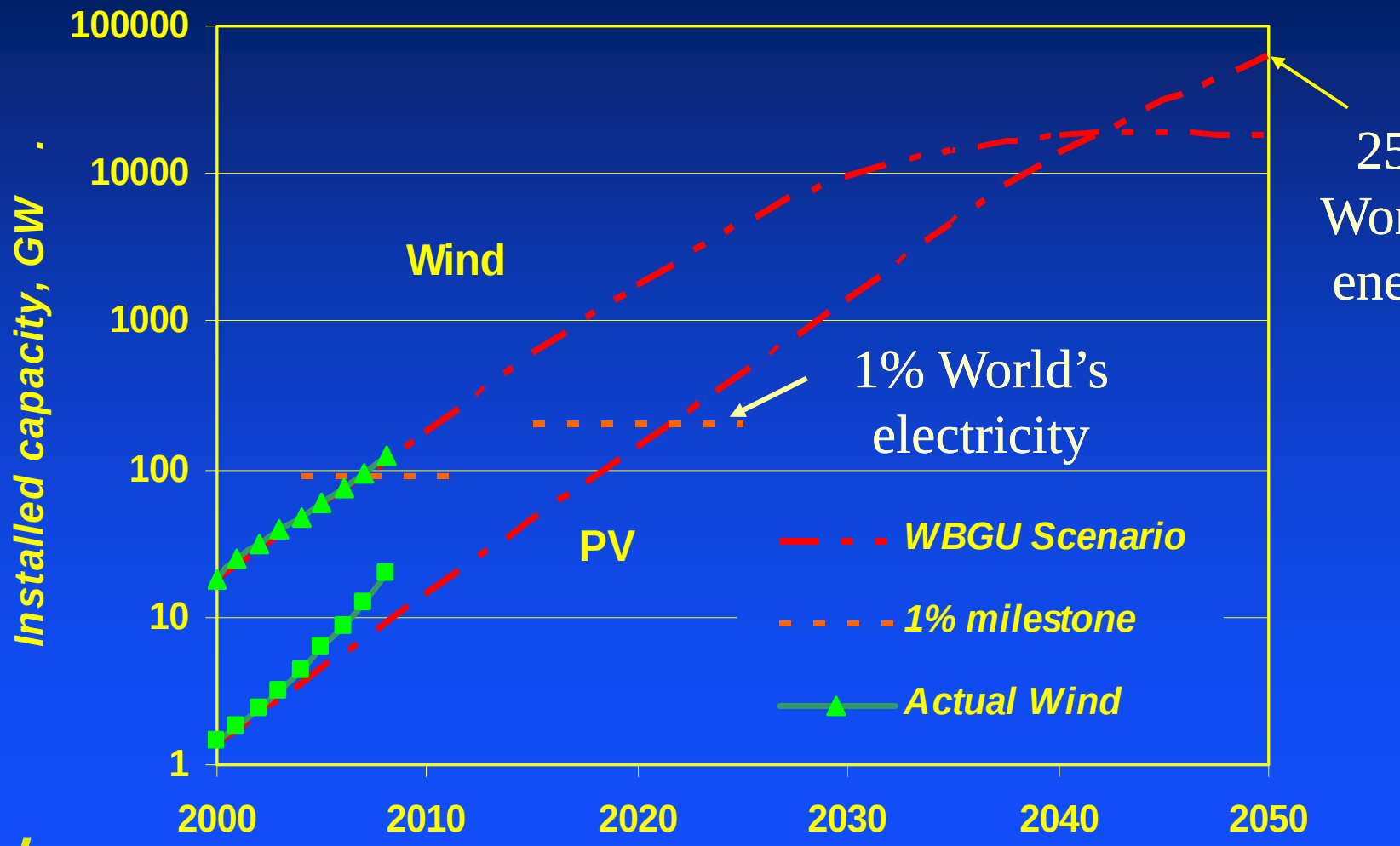
Annual capacity increase



Sources: Photon International, IAEA, GWEA

Photovoltaics - Electricity from Sunlight

“Submerged” progress



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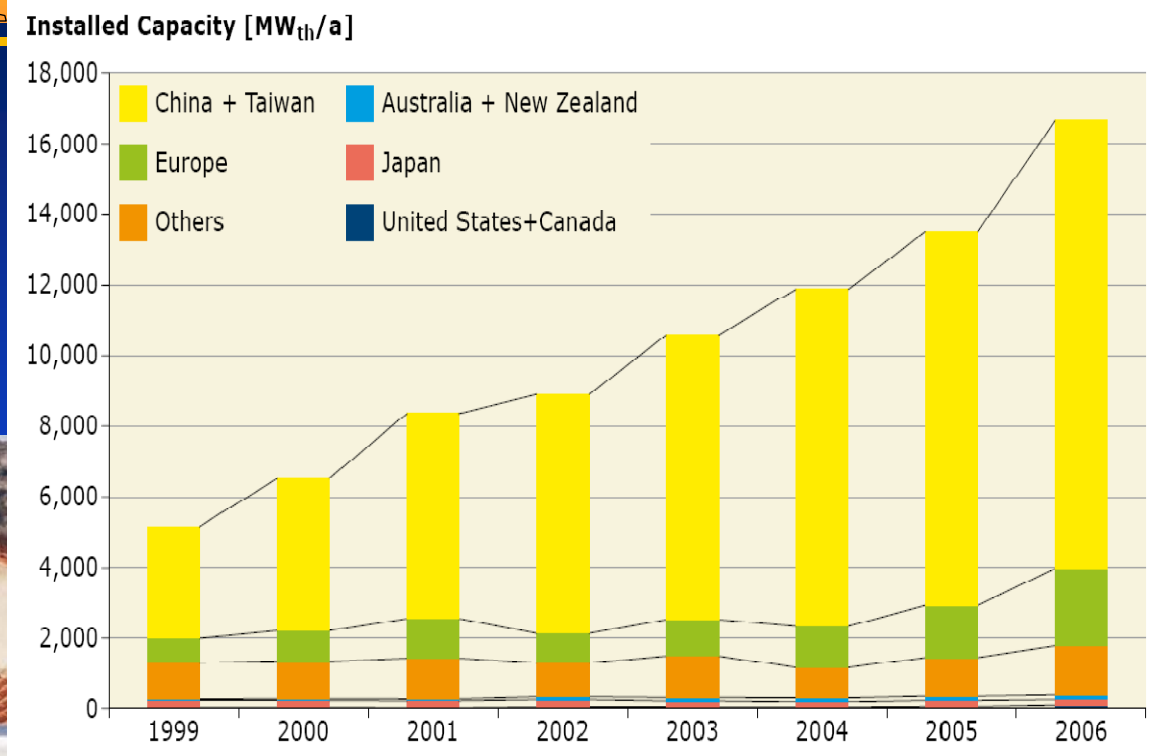
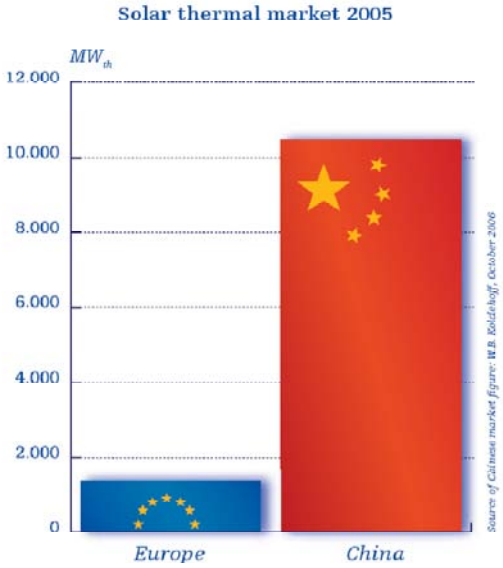
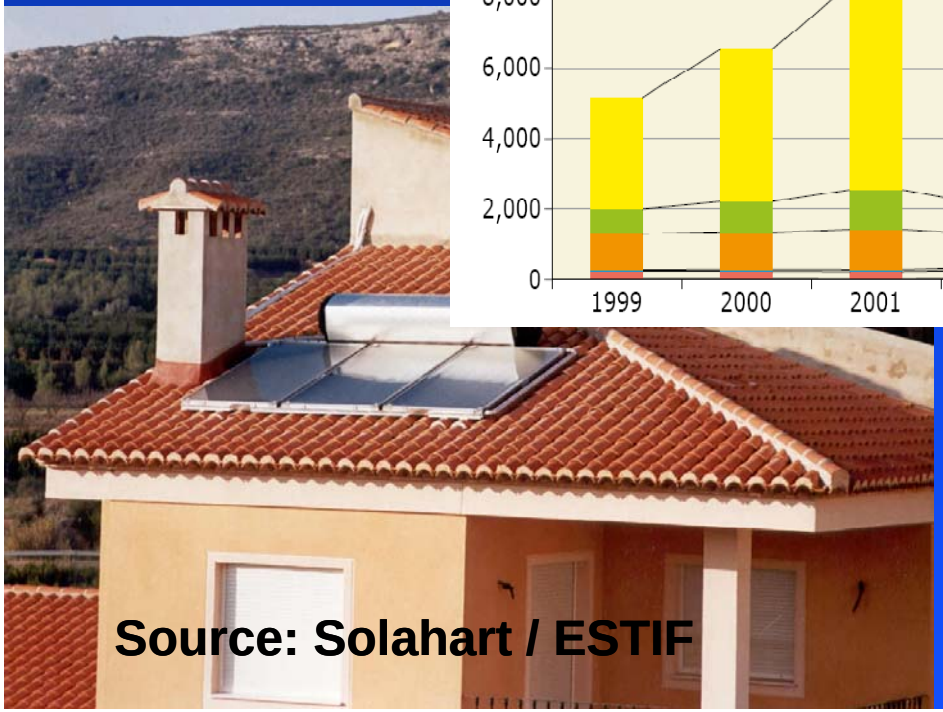
Solar heating







Source: Solahart / ESTIF

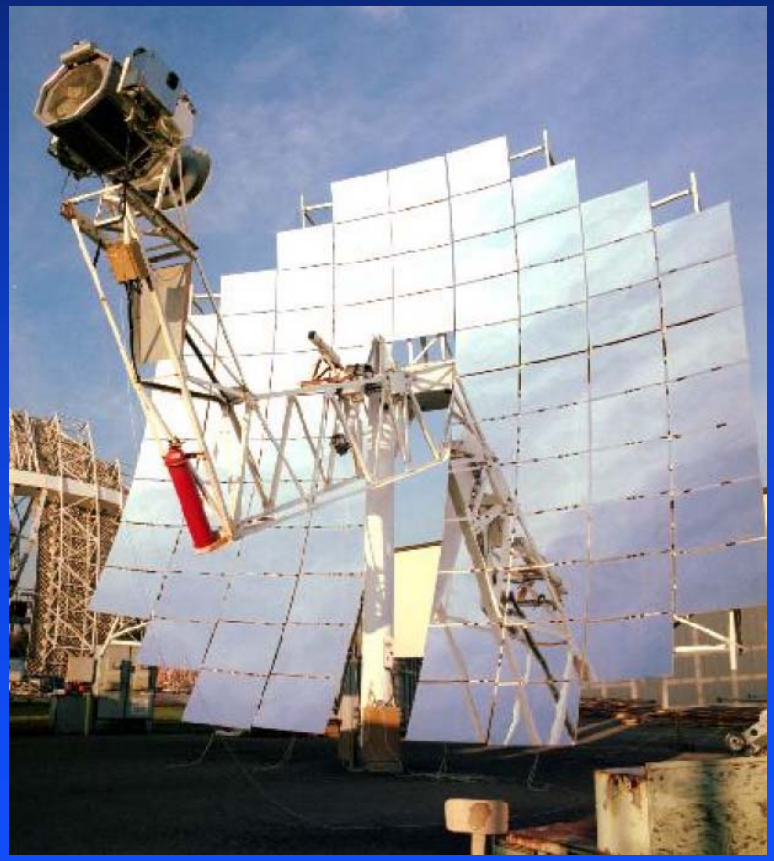
Concentrating Solar Power (CSP) 1

Parabolic trough

Power tower

Concentrating Solar Power (CSP) 2

Stirling engine



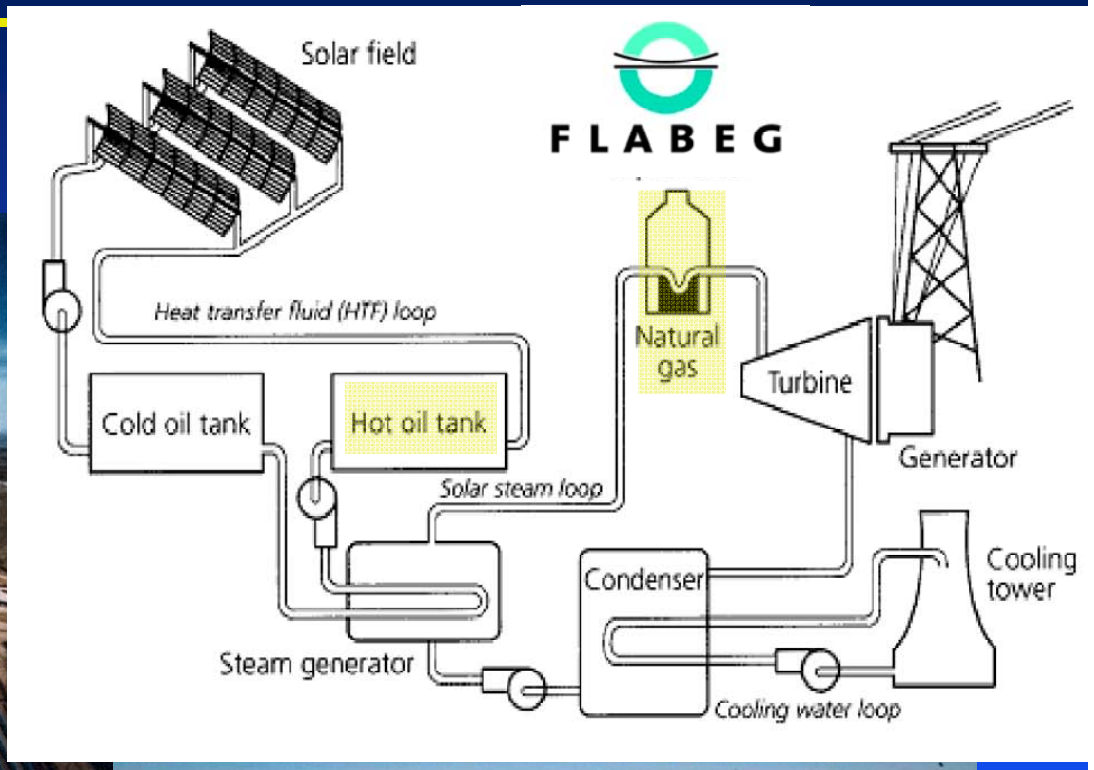
Photovoltaic receiver

Kramer Junction USA 354MW

Oil storage, gas boosting (25%)

Commenced 1989, 10.6% solar to electricity

Capex $2954/kWe, O&M 4.62c/kWh



Issues

Positives

. Integrate with fossil-fuel plant

. Heat storage relatively cheap?

. Lower capital cost than standard PV (in past)

Negatives

. Compete on wholesale market against wind & fossil-fuels

. Clear sky, water needed

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Ultimate costs versus PV

PV panels as cheap as optical elements of concentrators?

(then don't need rest of system, optical accuracy etc.)

Troughs: $250/m^2

Mirrors: $40/m^2

Heliostats: $125-$159/m^2

Mirrors: $13/m^2 ?

Thin-film PV panels: already $110/m^2 (First Solar Q4 2006)

Eventually $30/m^2 ?

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Photovoltaic Applications

Conventional Generators

PV Central Station

PV Mini-Utility

PV Residential

Diesel

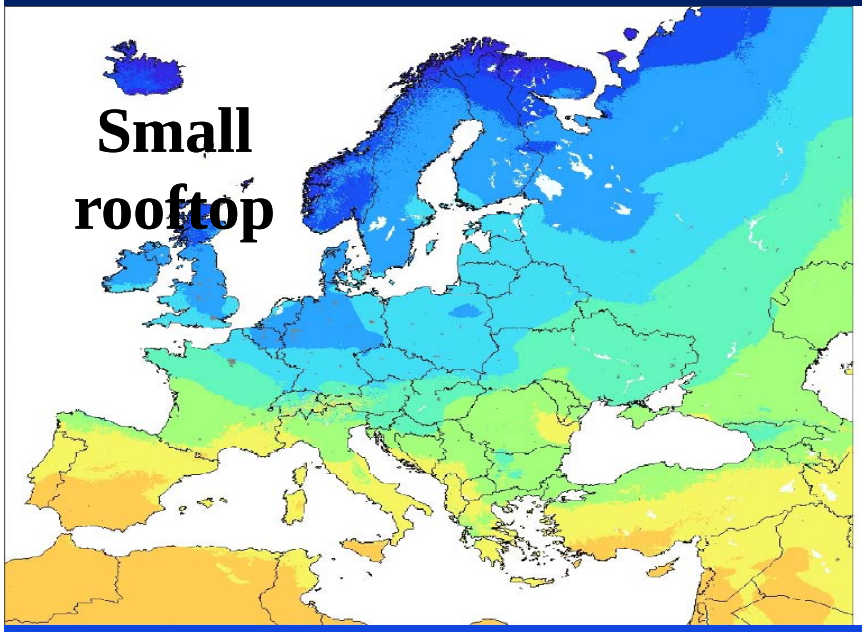
PV RAPS

Thermal overload

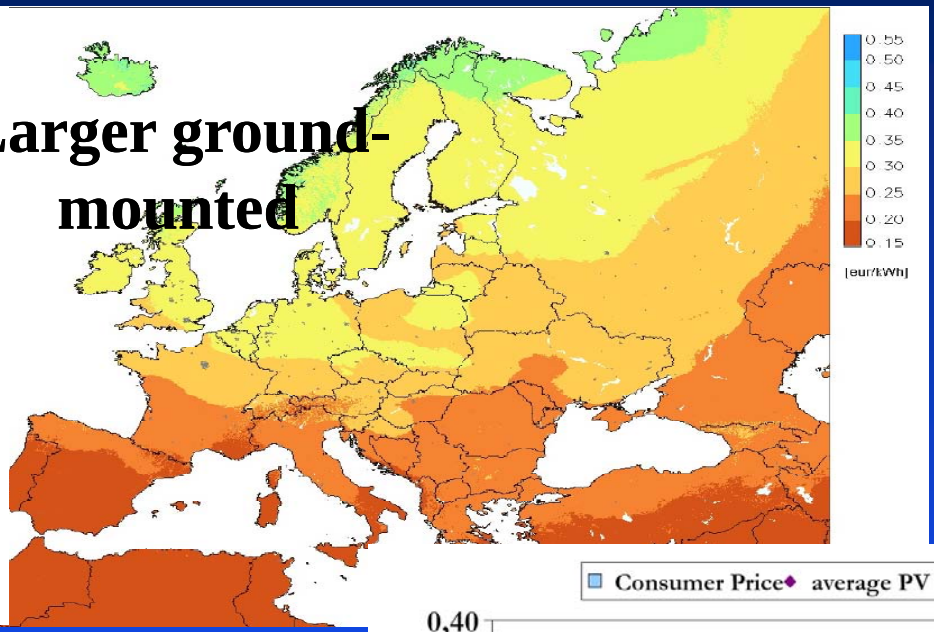
Photov

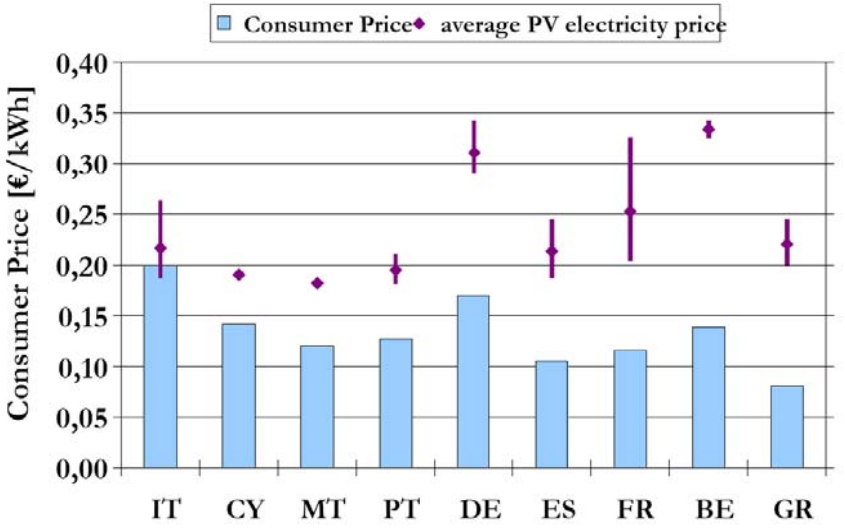
Grid parity: Europe

Small rooftop



Larger ground-mounted





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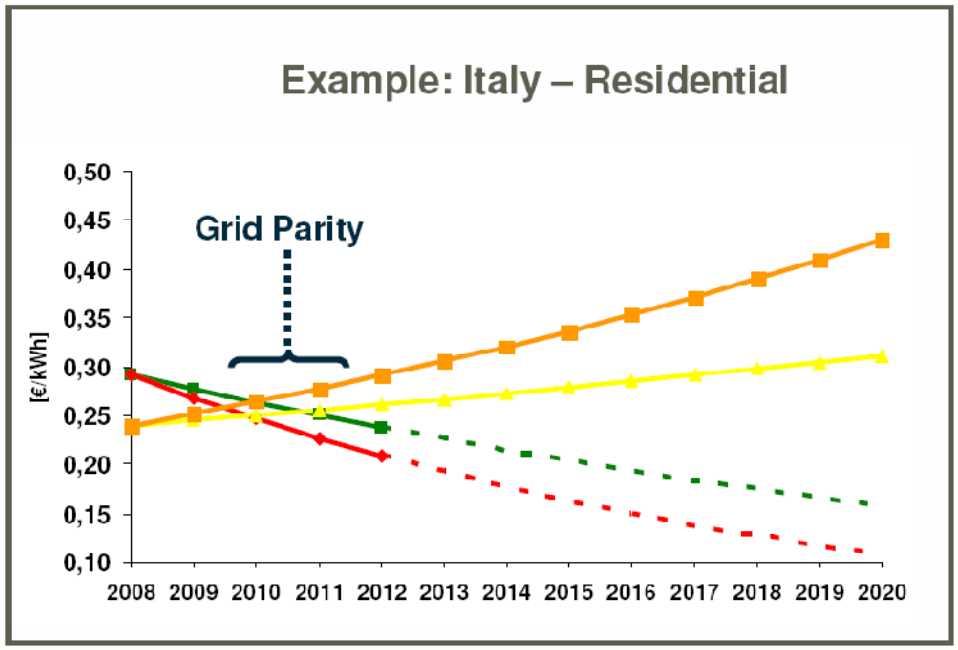
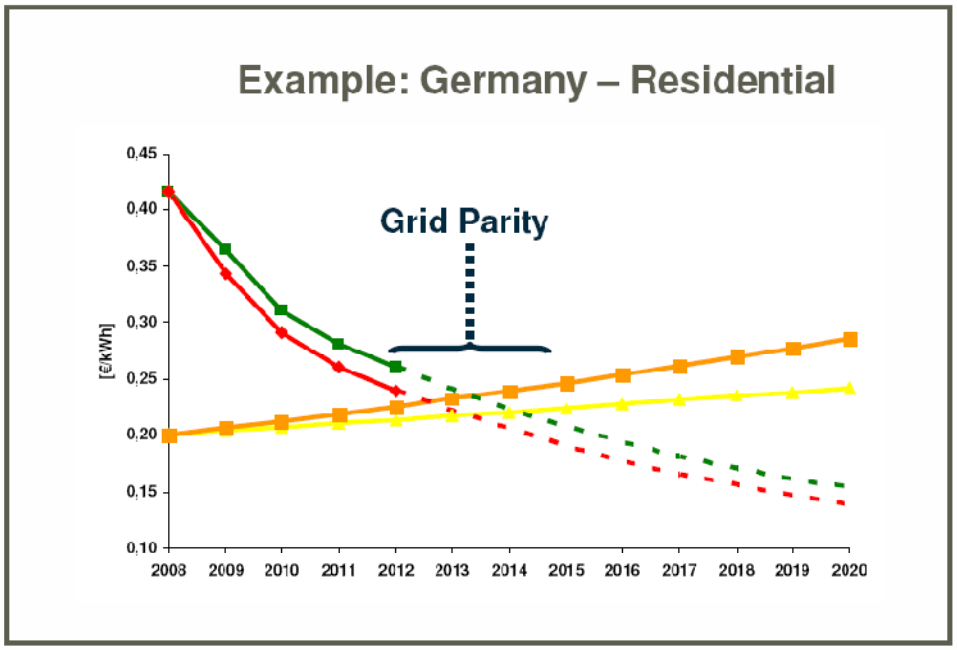
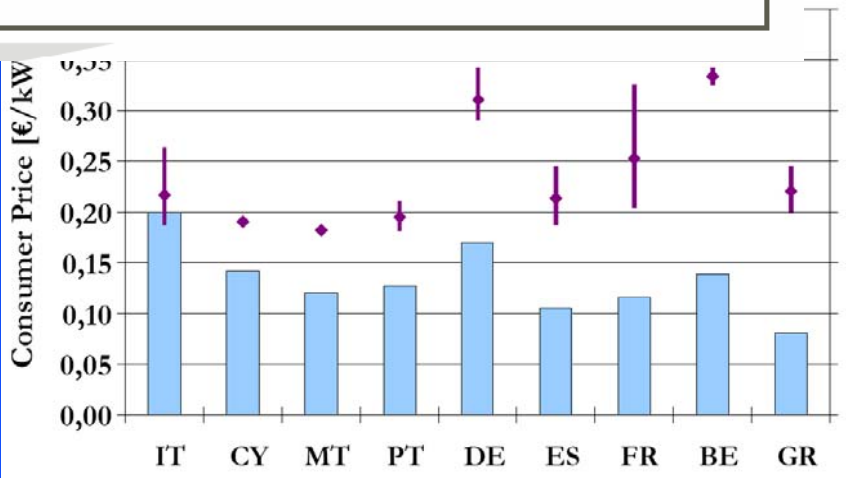
Grid parity: Europe







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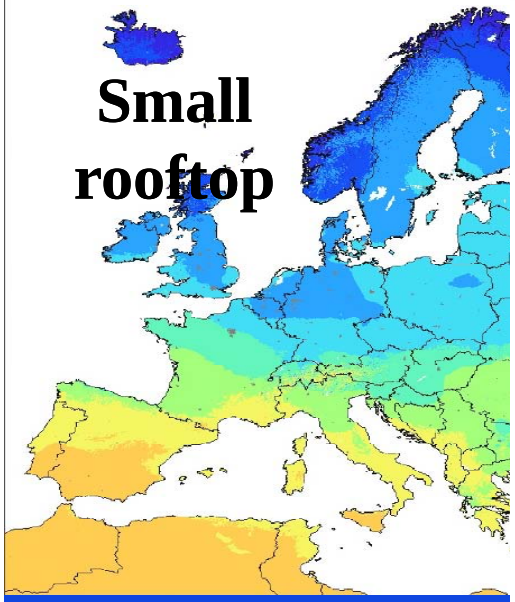

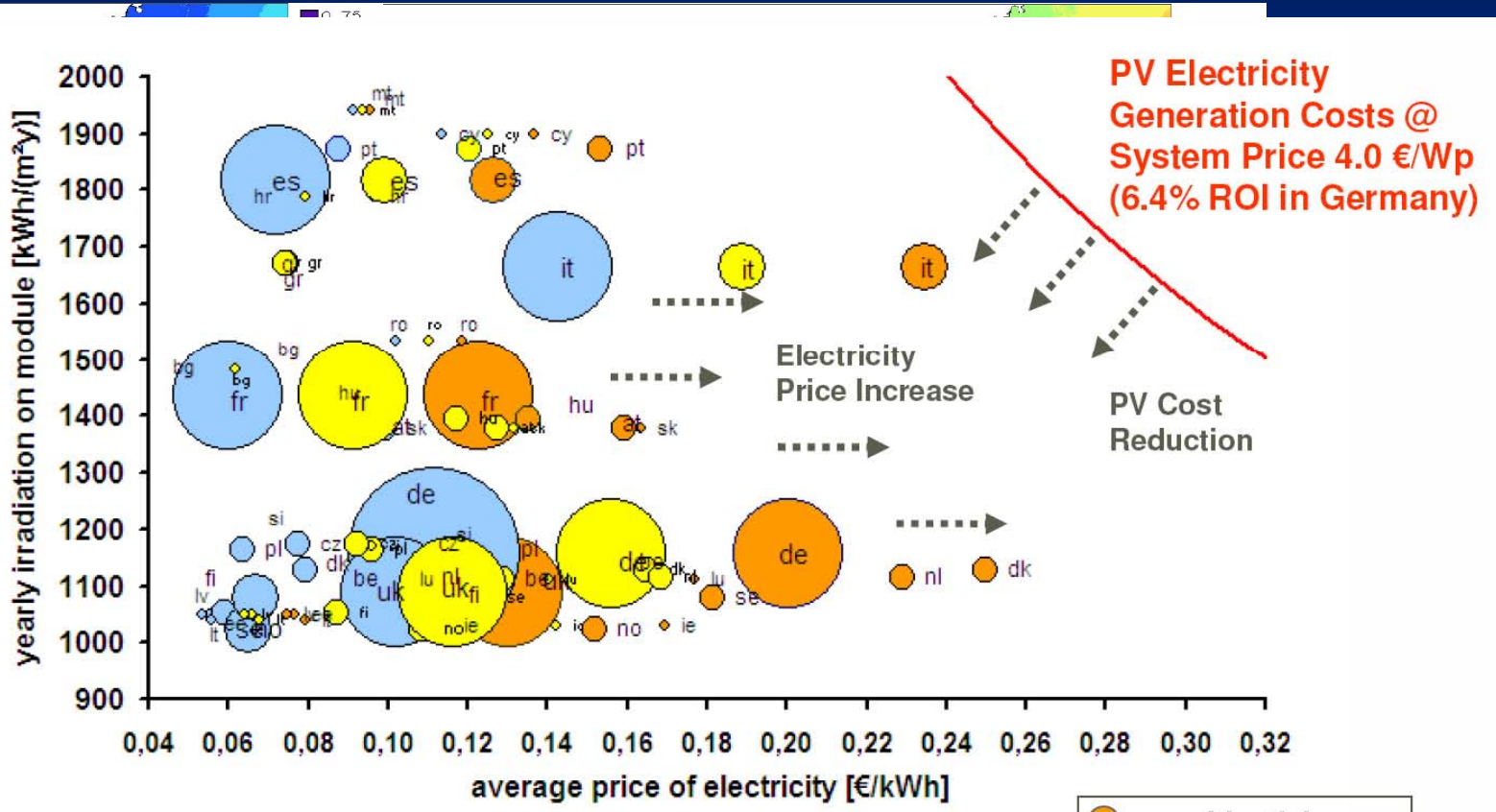

Assumptions: Operation & Maintenance: 1.5% of Capex; System Lifetime 25 years; Performance Ratio 80%; WACC 6.4%

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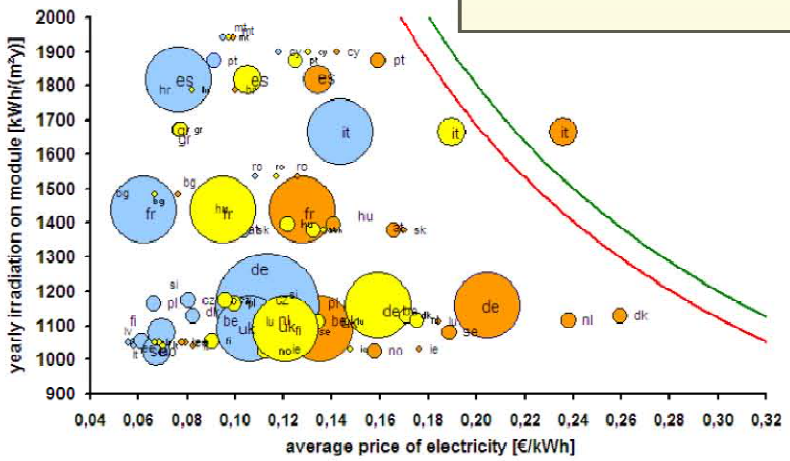
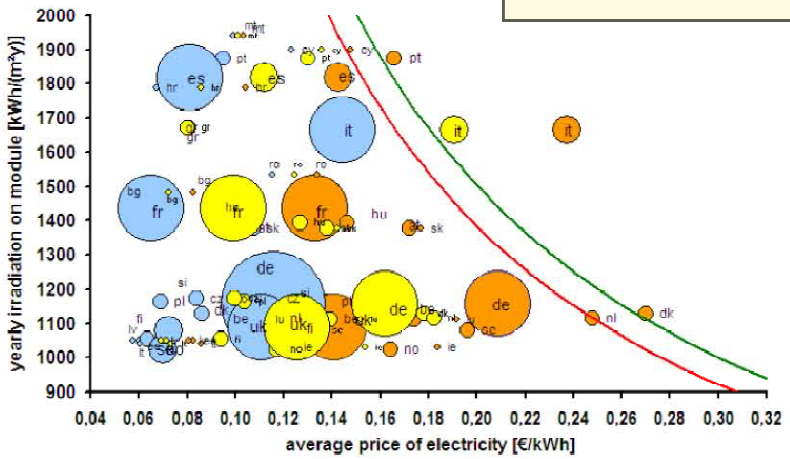
2010

Total Market: 3.162 TWh
Grid Parity Accessible Market: 74 TWh (2 %)



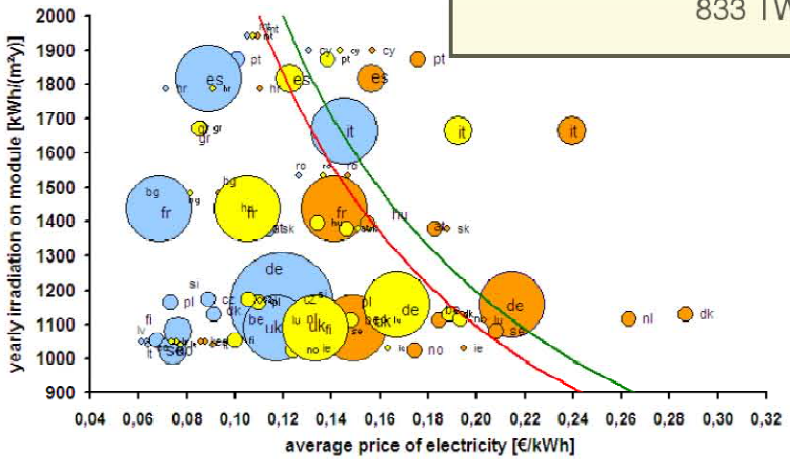
2012

Total Market: 3.286 TWh
Grid Parity Accessible Market: 208 TWh (6 %)



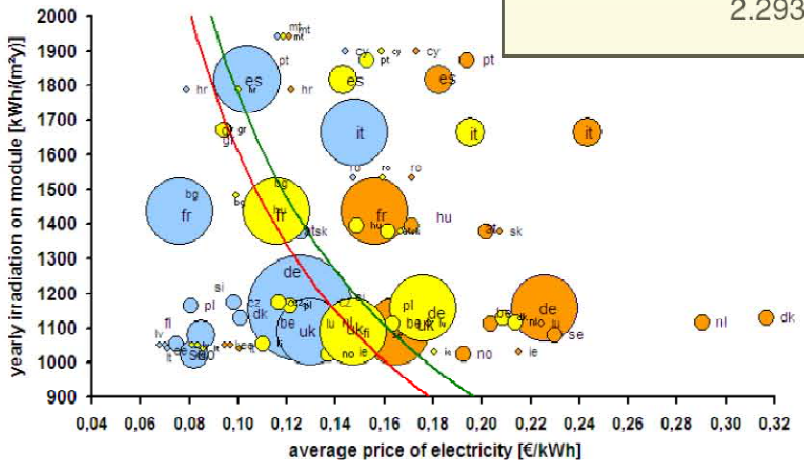
2015

Total Market: 3.484 TWh
Grid Parity Accessible Market: 833 TWh (24 %)



2020

Total Market: 3.857 TWh
Grid Parity Accessible Market: 2.293 TWh (59 %)



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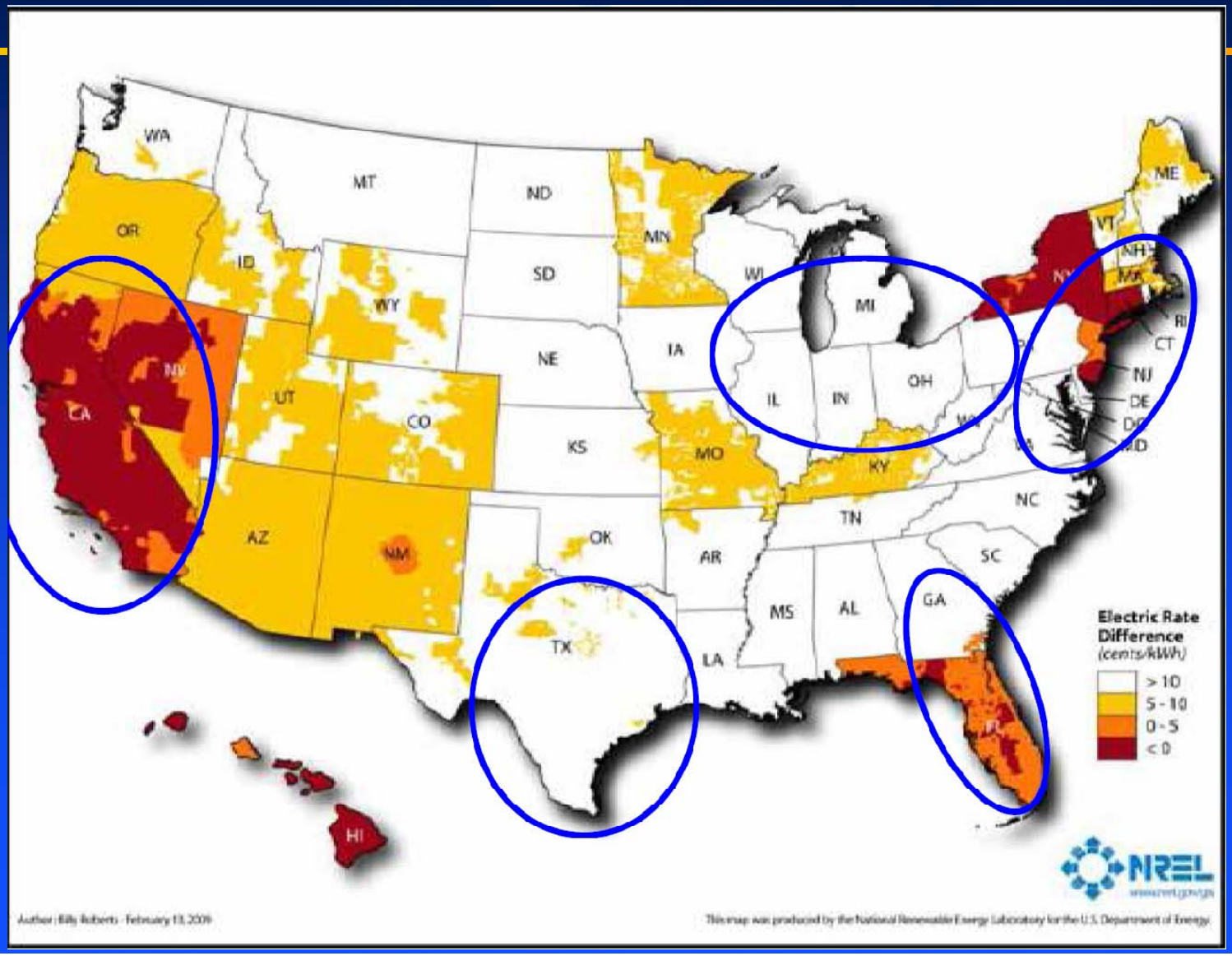
Grid parity: USA



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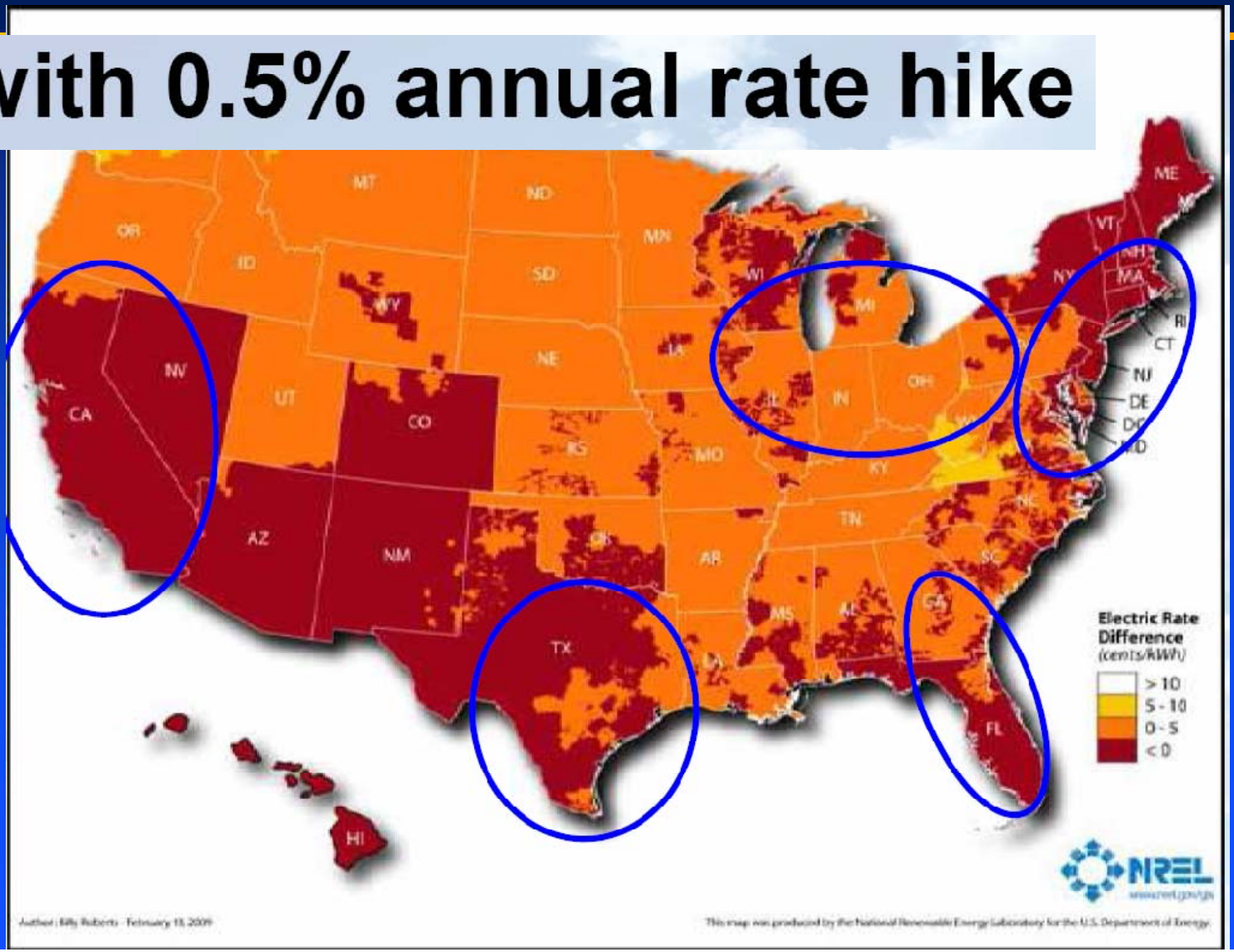
Grid parity: USA

2015 with 0.5% annual rate hike



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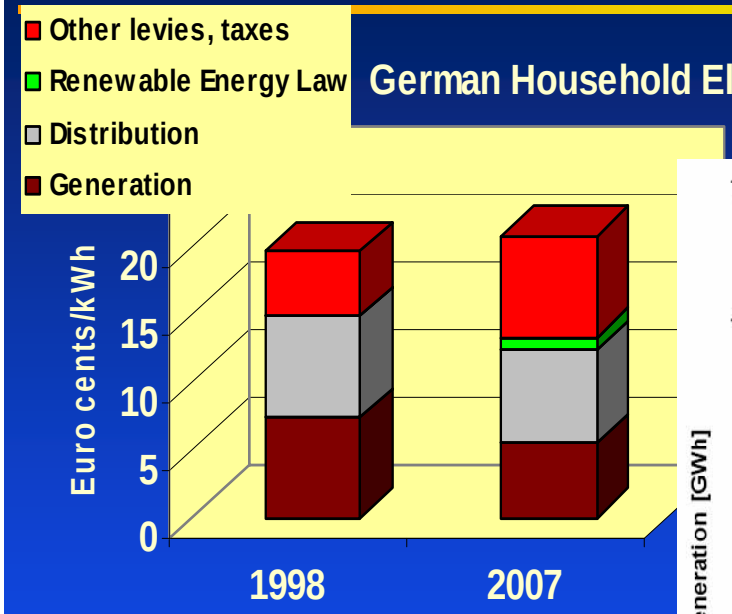
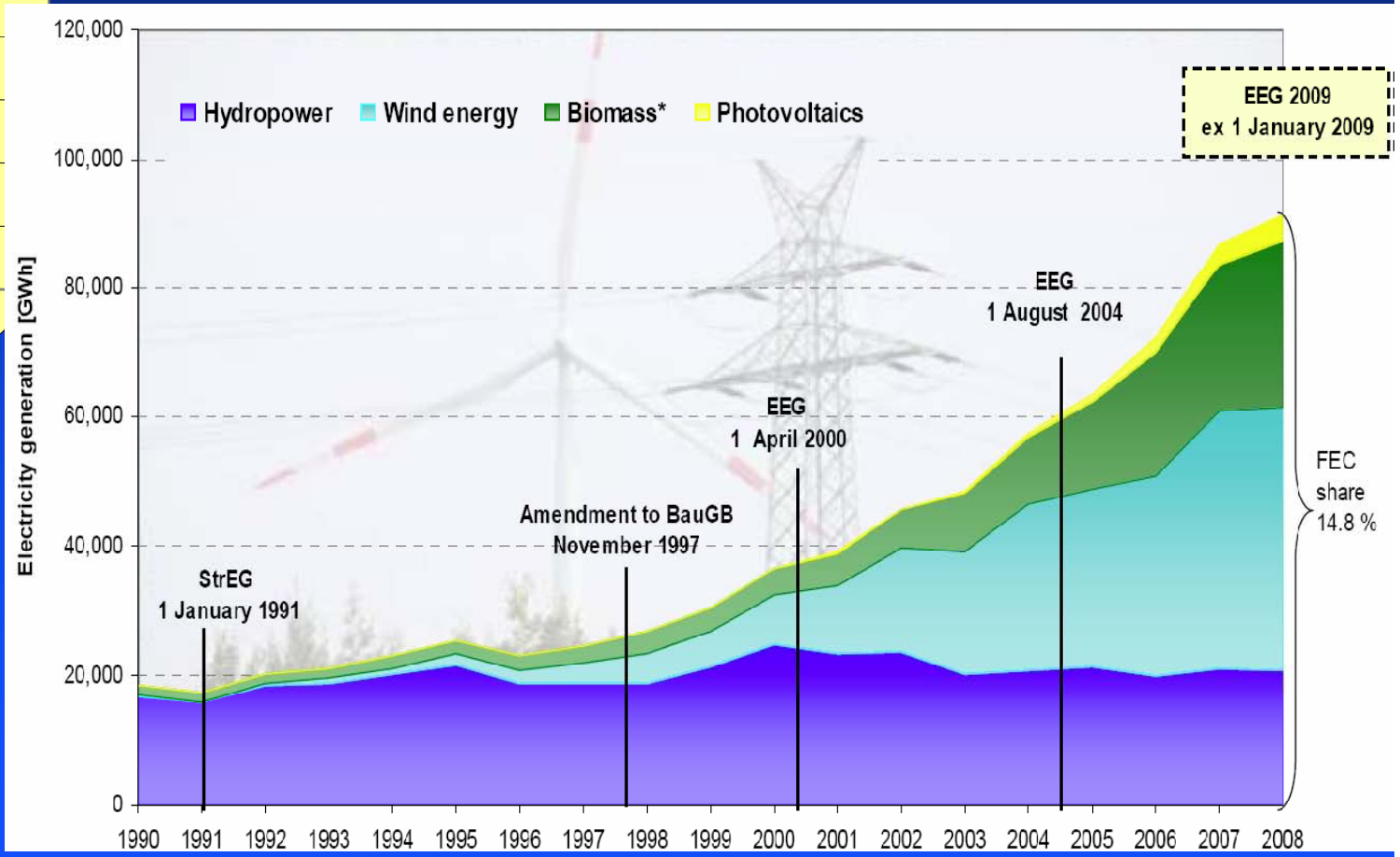
Germany: feed-in tariff results





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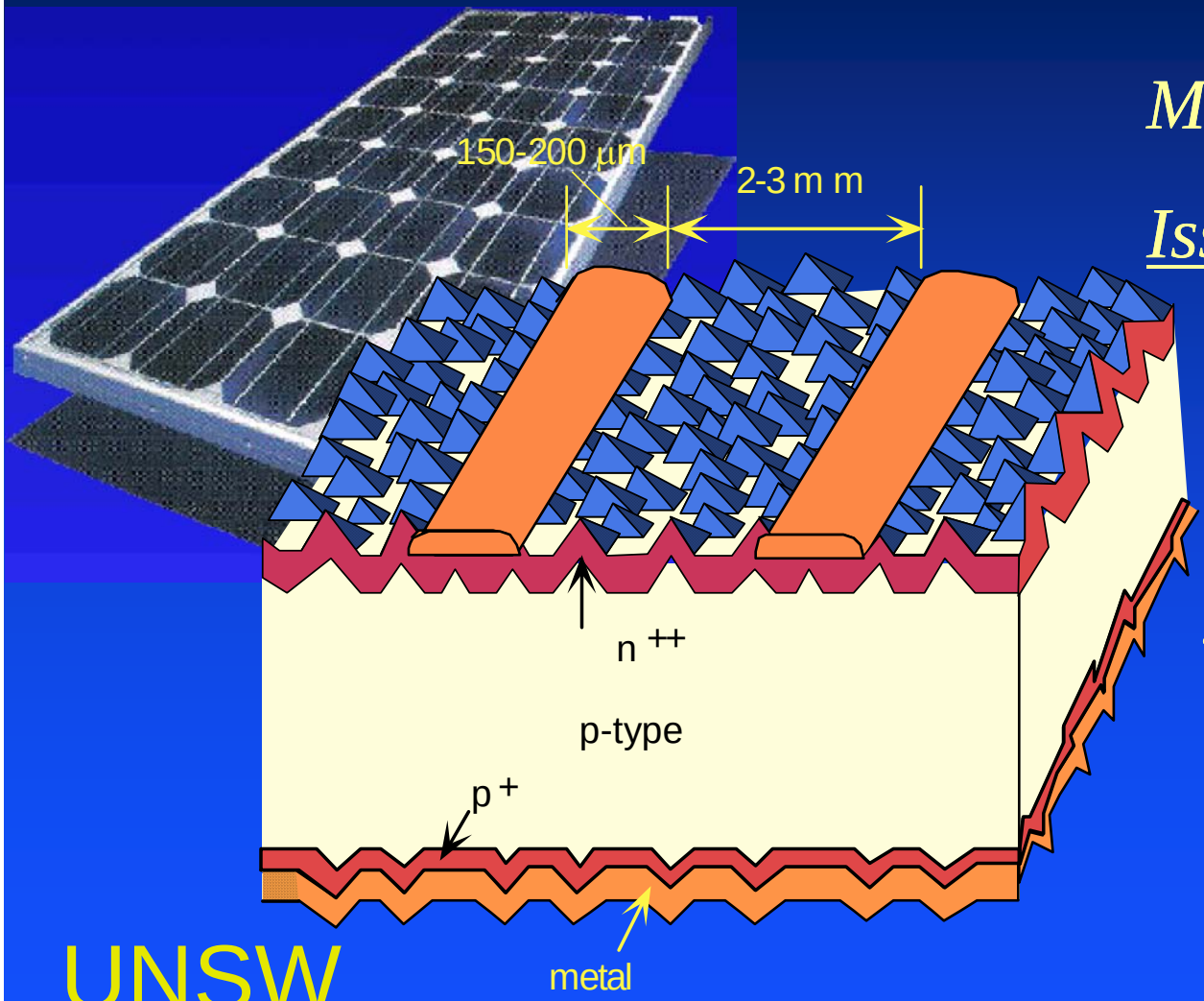
First generation cells



More Si than microelectronics

Issues

. thinner cells

. simpler Si purification

. higher conversion efficiency

Second Generation: thin-film

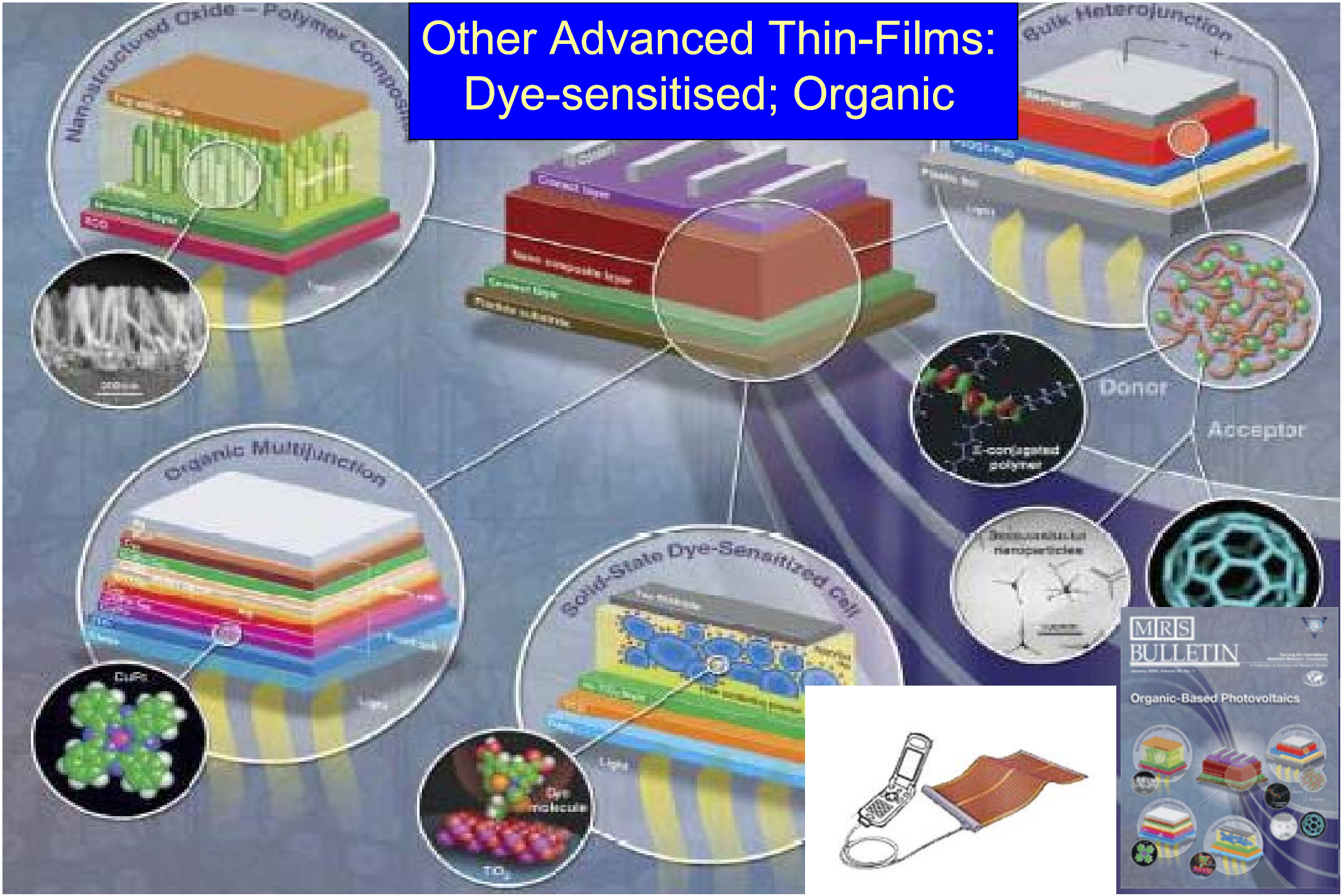
Advantages

- *low materials cost*
- *large manufacturing unit*
- *fully integrated modules*
- *aesthetics, ruggedness?*

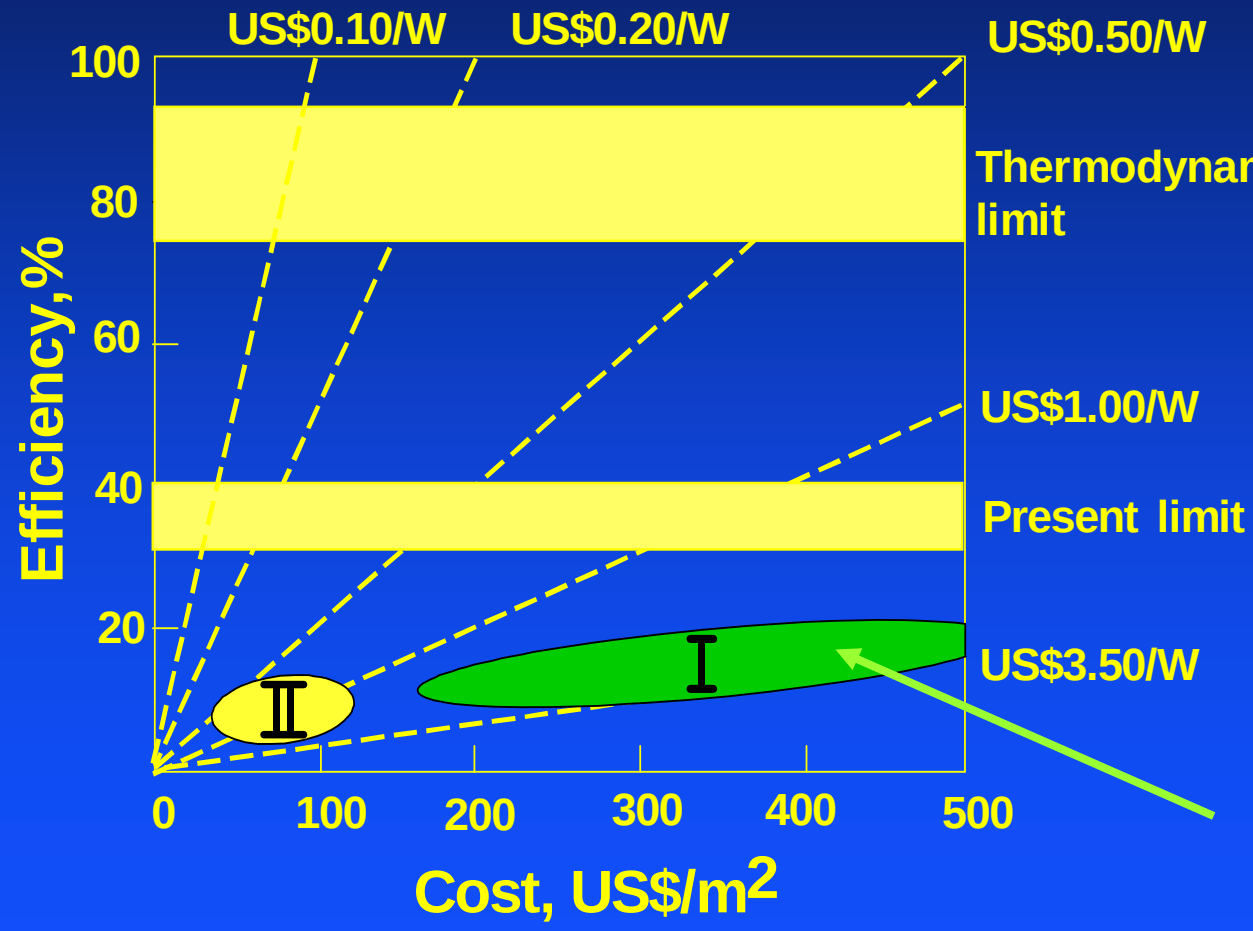
Thin-film Technologies

- ***Silicon***
  - *amorphous*
  - *microcrystalline*
  - *polycrystalline*
- ***Chalcogenide*** *(polycrystalline)*
  - *CIS, CIGS [$Cu(In,Ga)(Se,S)_2$]*
  - *CdTe*
- ***Dye sensitised, Organics***

Other Advanced Thin-Films: Dye-sensitised; Organic



Efficiency/ cost



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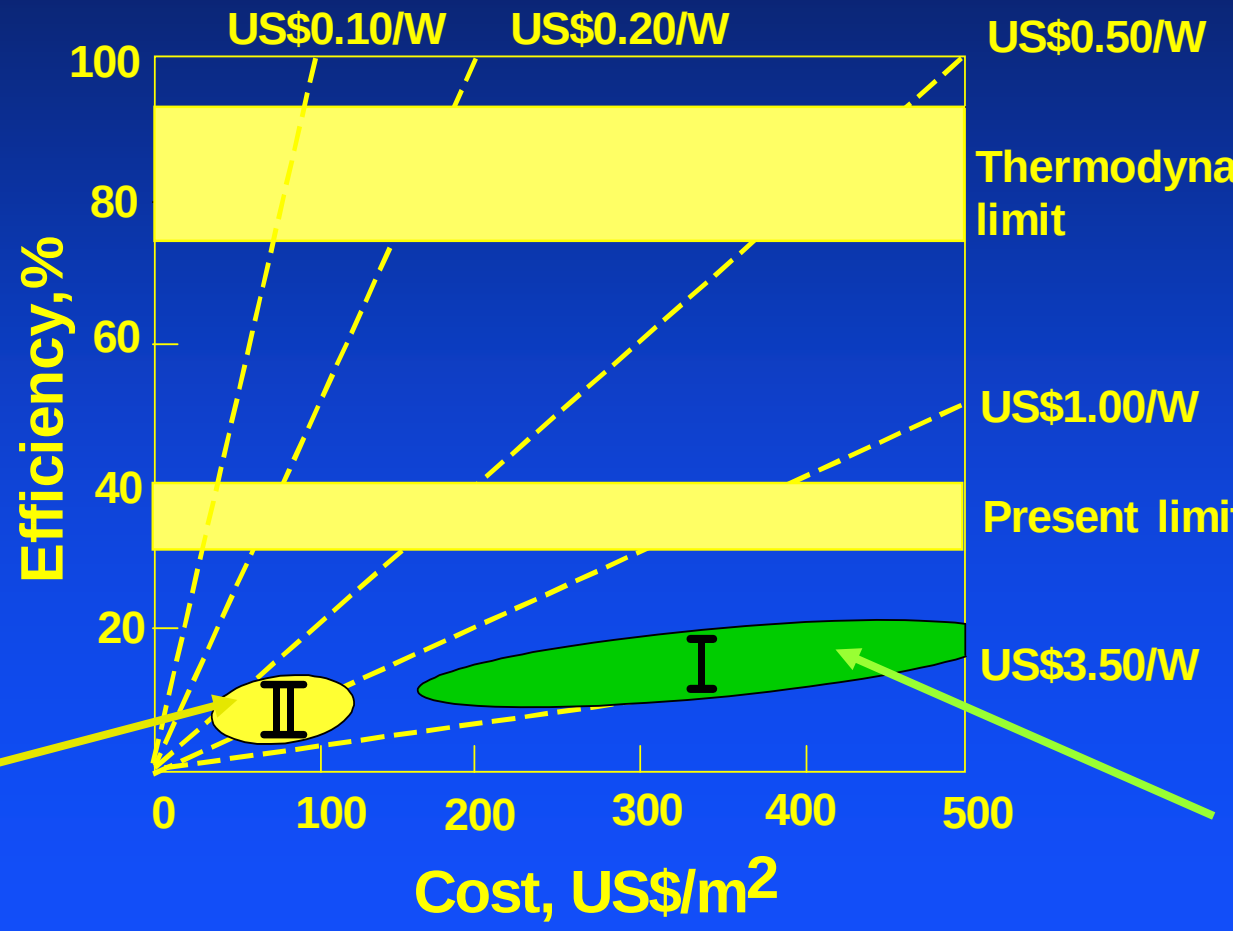
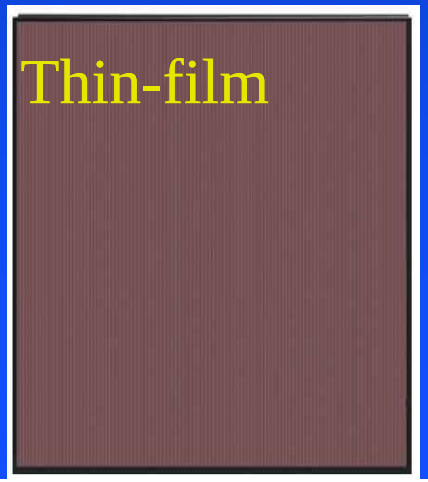
Photovoltaics - Electricity from

Efficiency/ cost

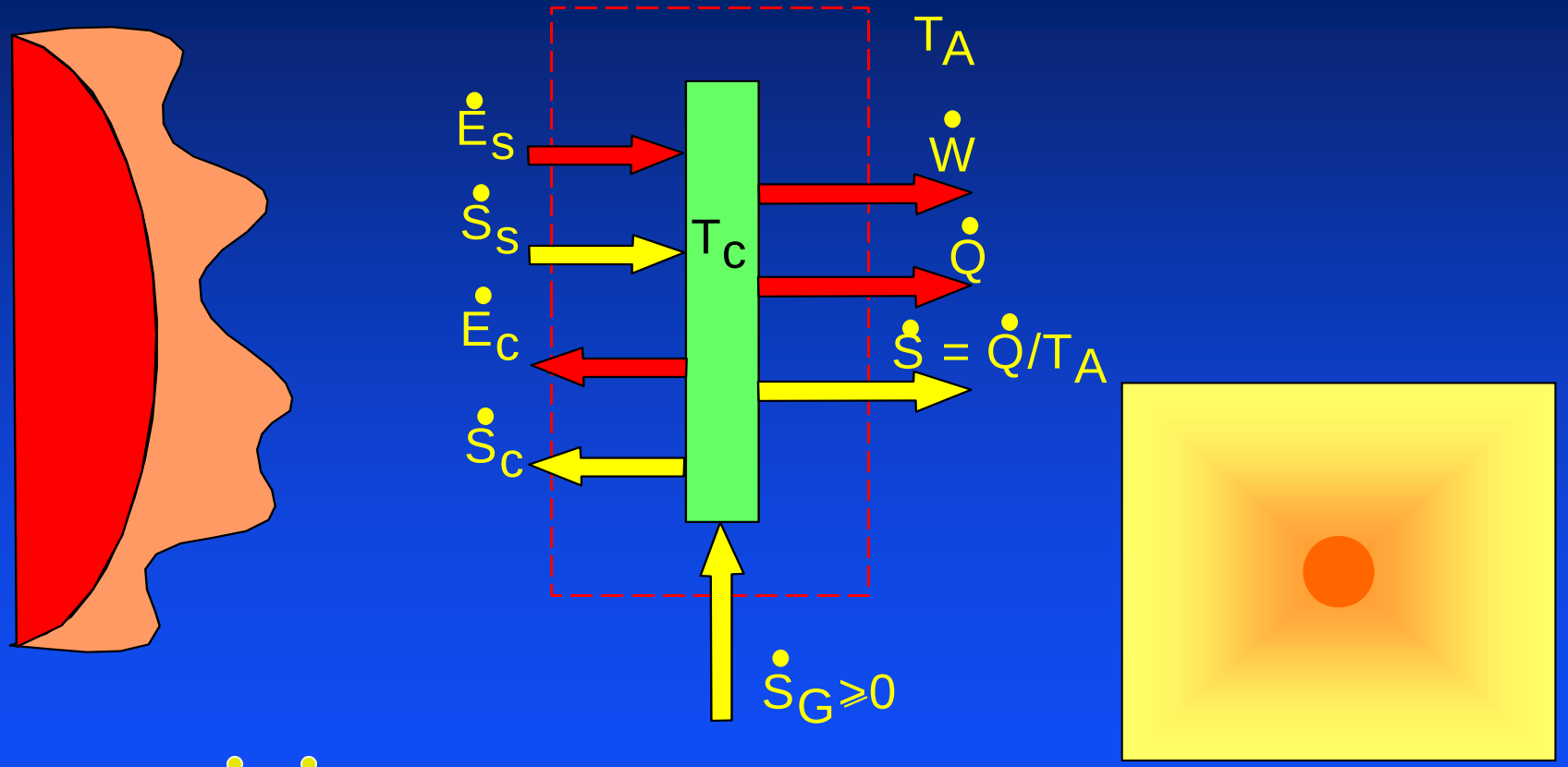




Includes dye, organic

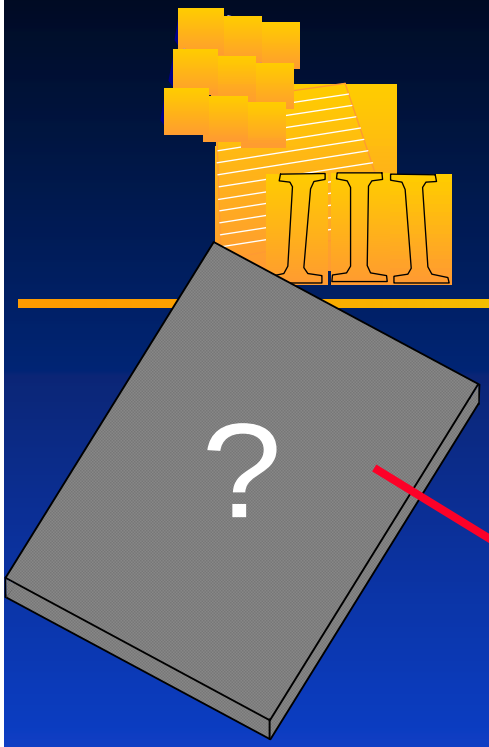
Photovoltaics - Electricity fro

Thermodynamic efficiency limits

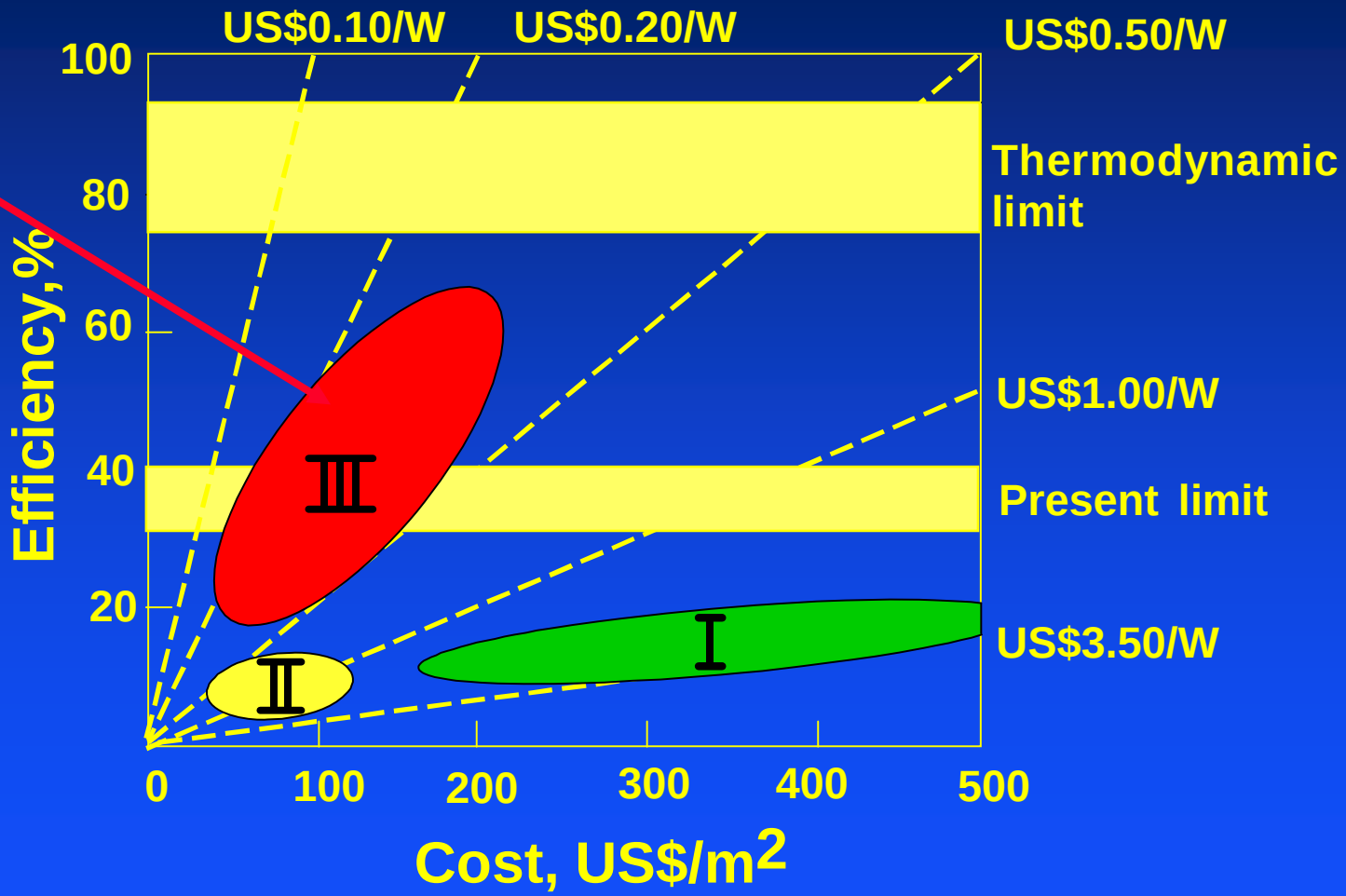


$$\eta \leq (1-T_A\dot{S}_s/\dot{E}_s) = 93.3\% \text{ (direct)} = 73.7\% \text{ (global)}$$

The 3 generations



- *high-efficiency*
- *thin-film*
- *abundant*
- *non-toxic*
- *durable*



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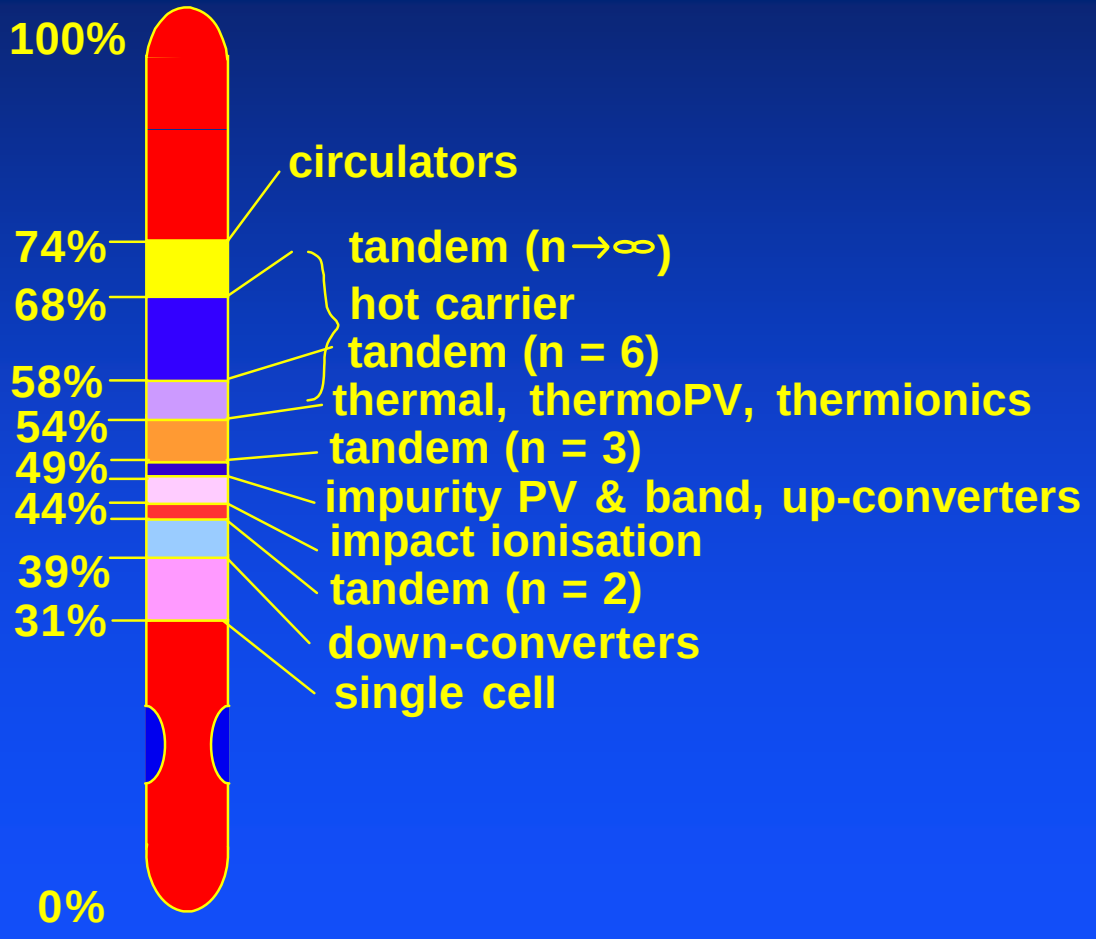
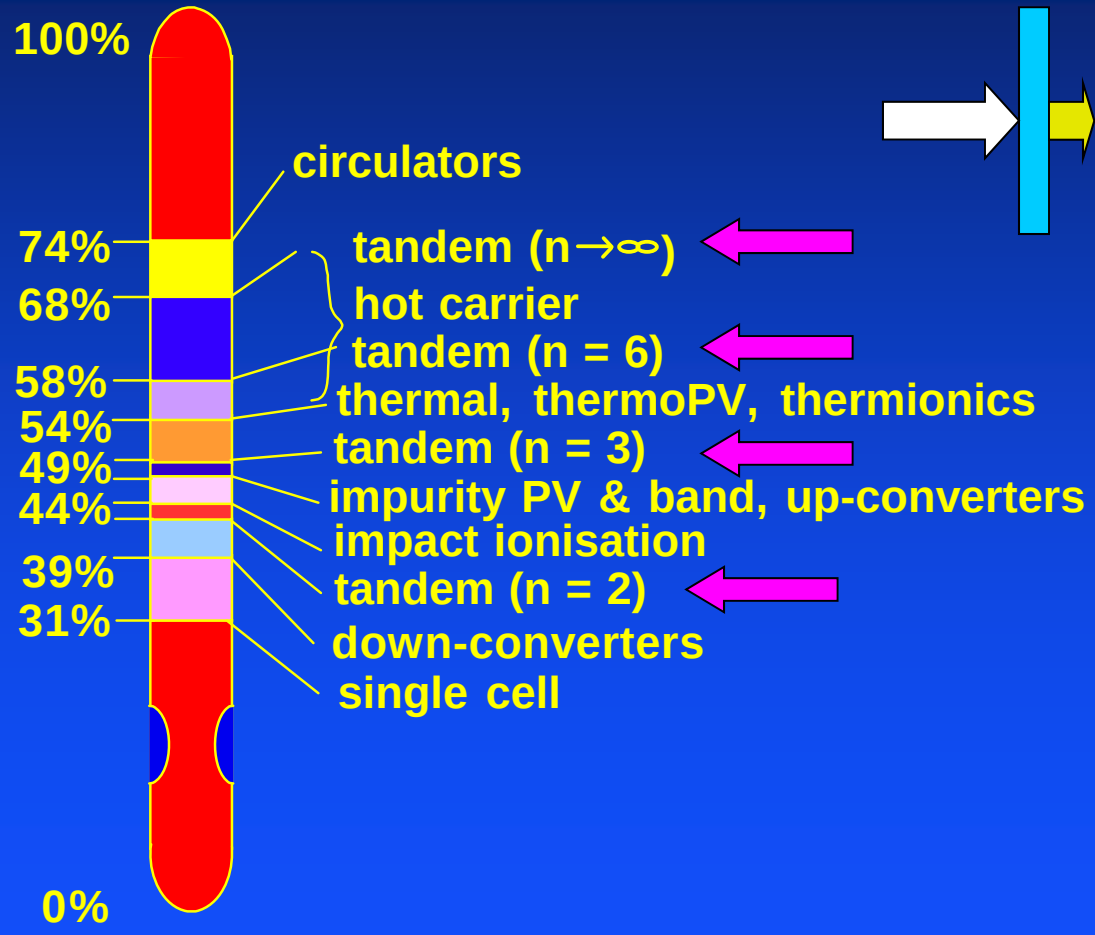
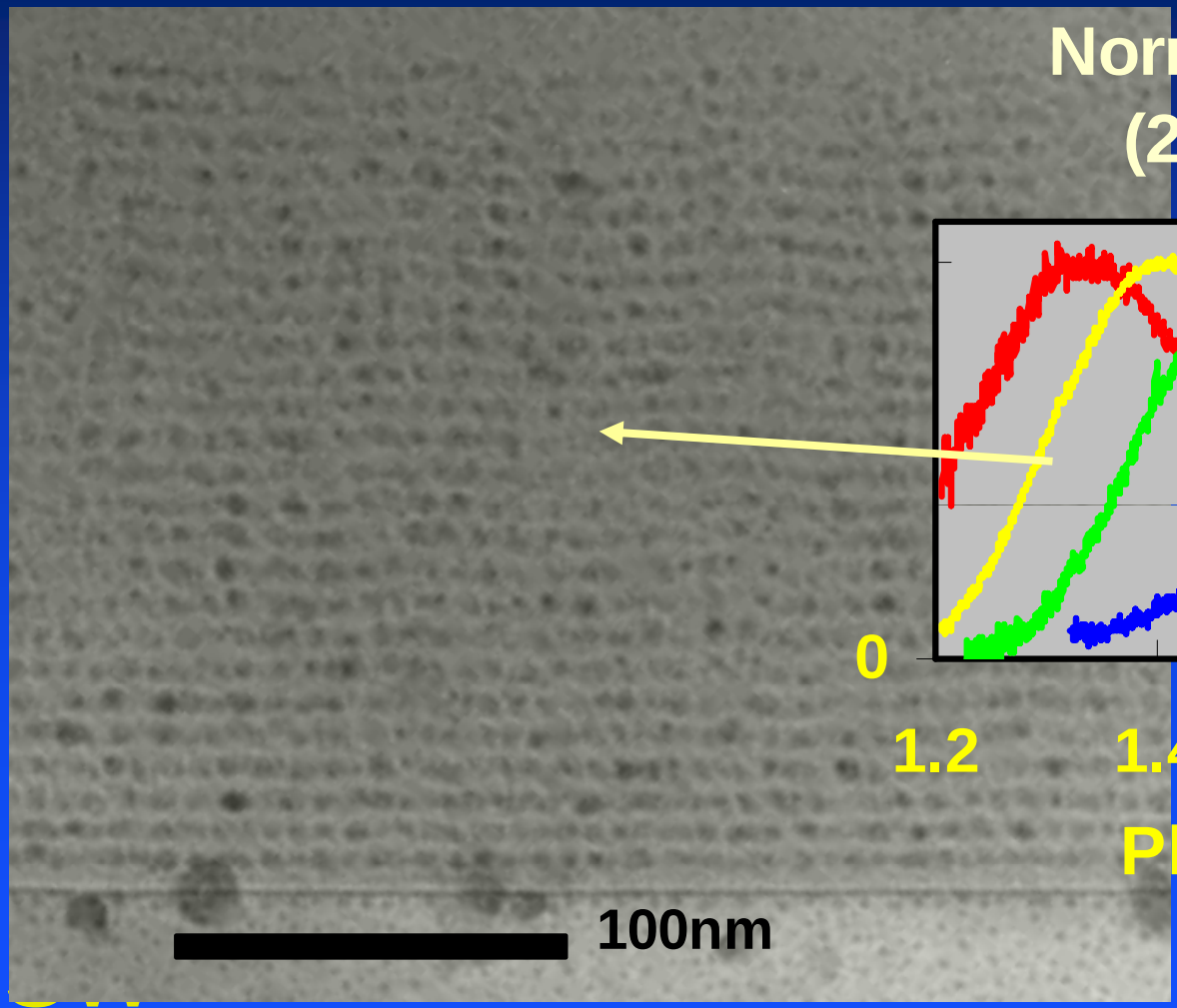
Third generation options



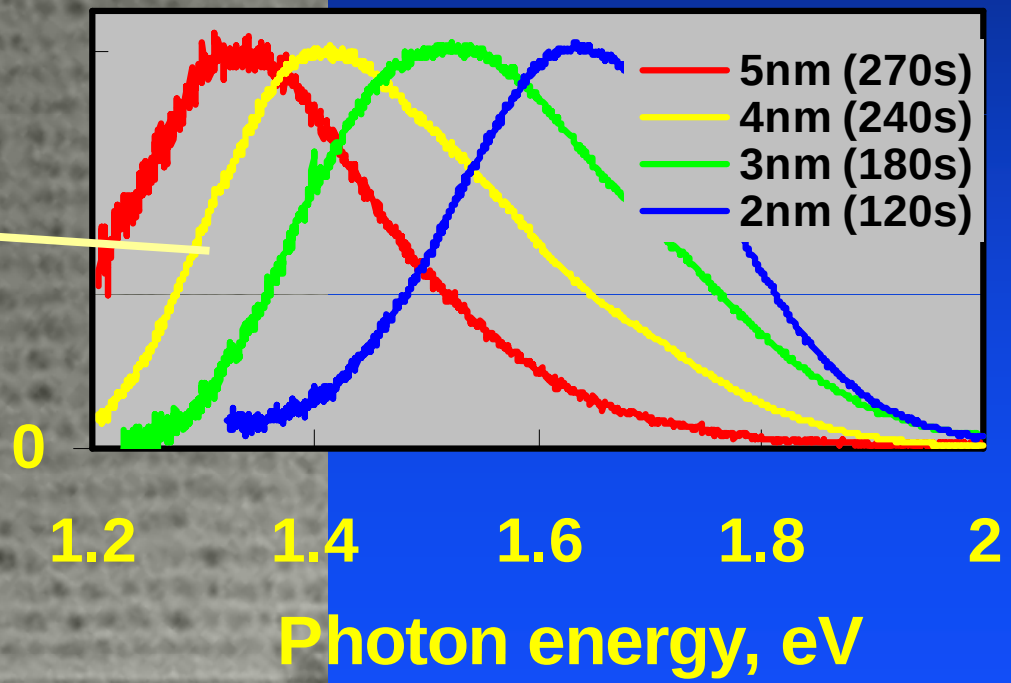
Third generation options



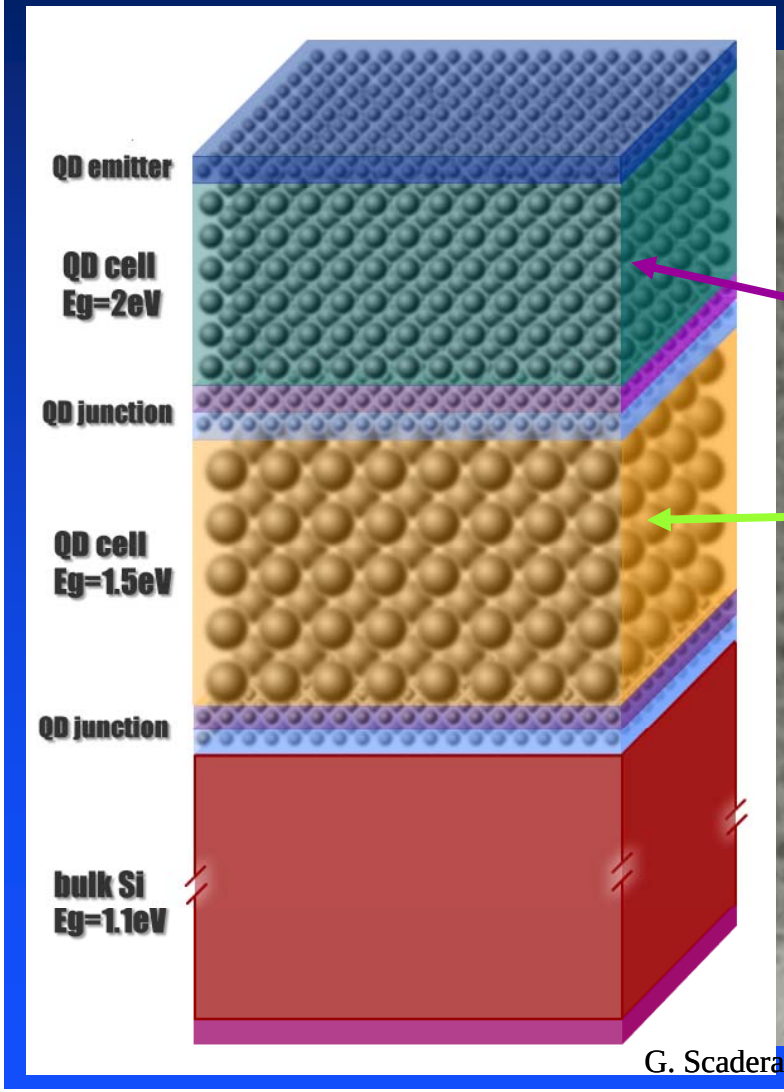
E_g control - photoluminescence

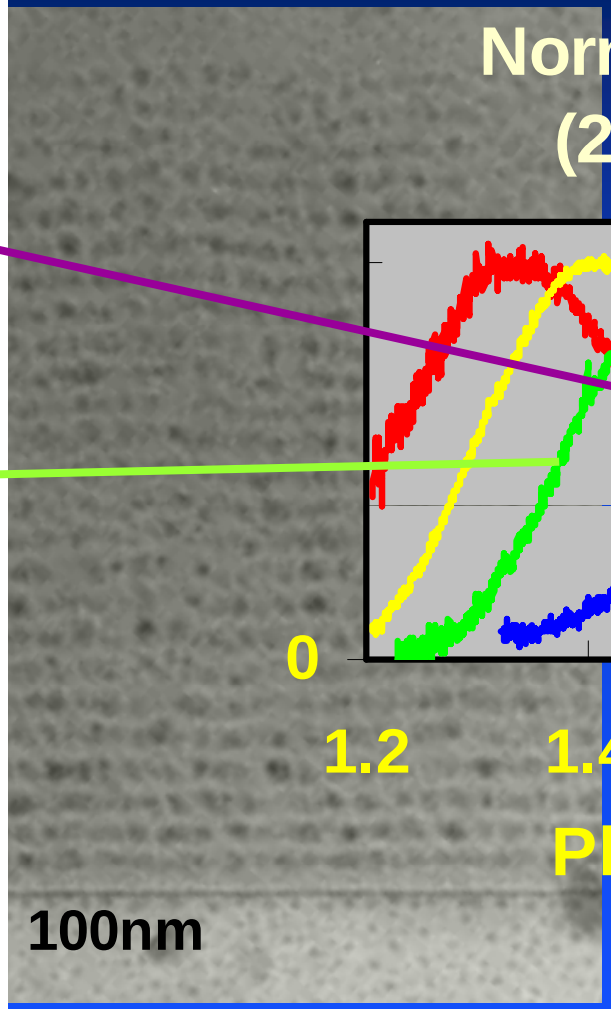


Normalised PL Spectra (2-5nm dots; 300K)



Si quantum dot tandem cell





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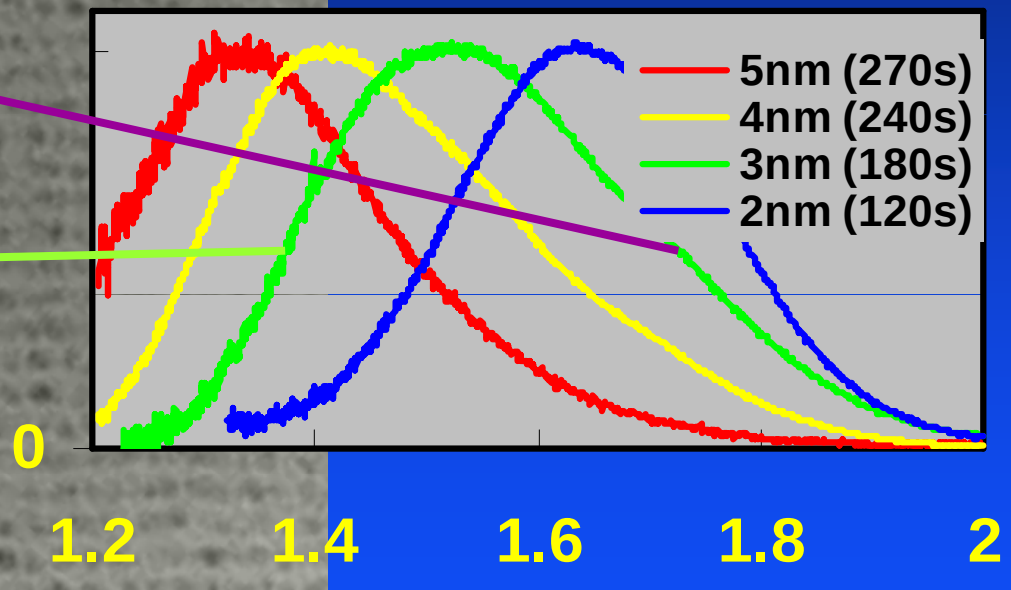
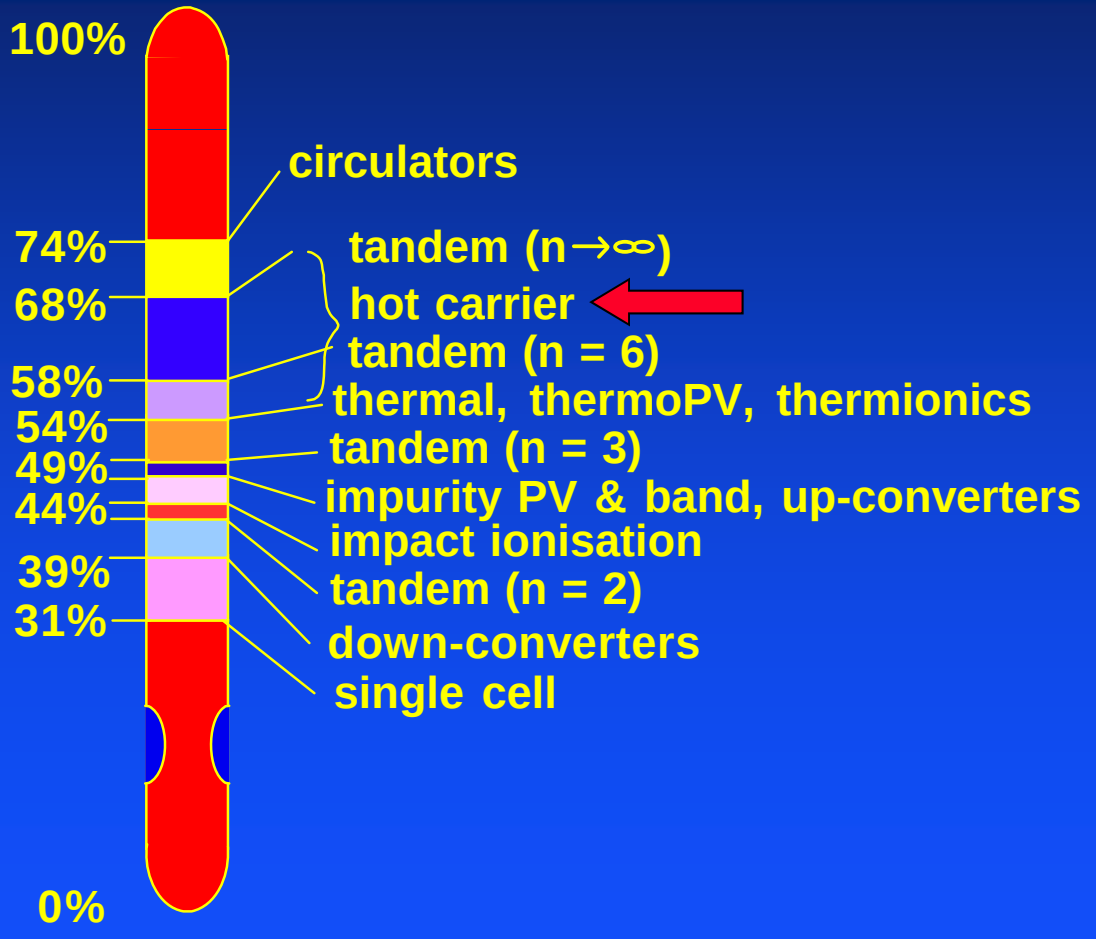
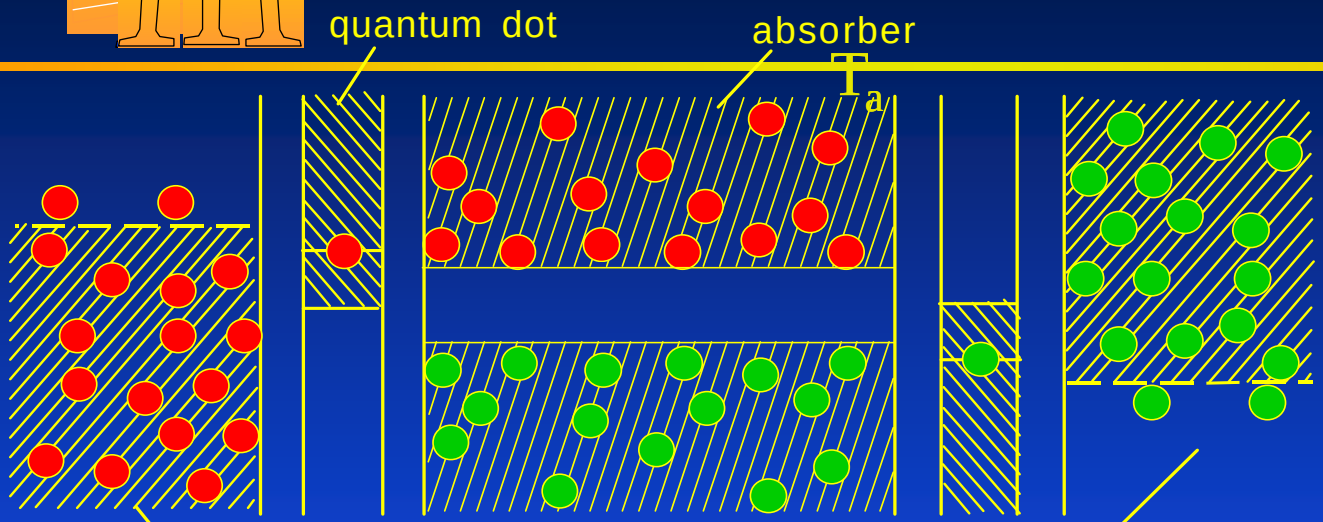


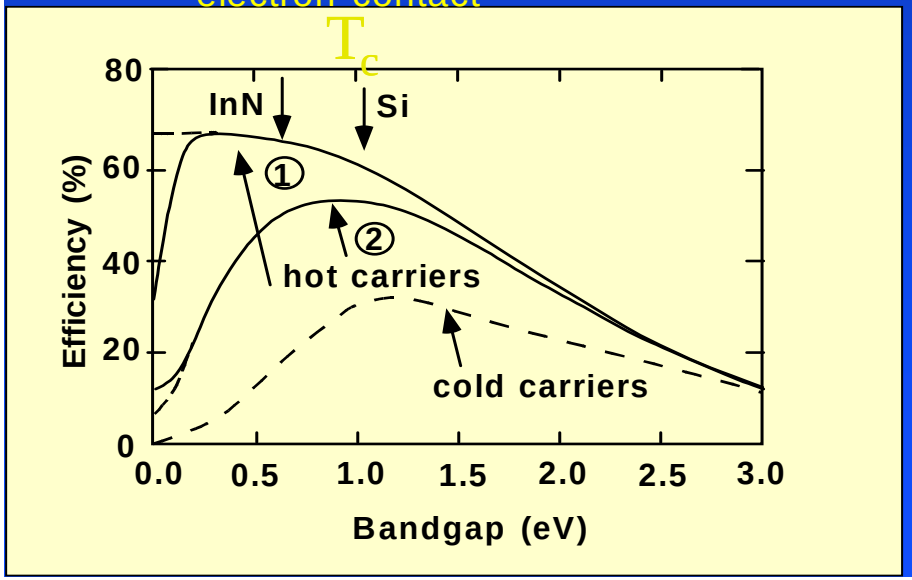
Third generation options

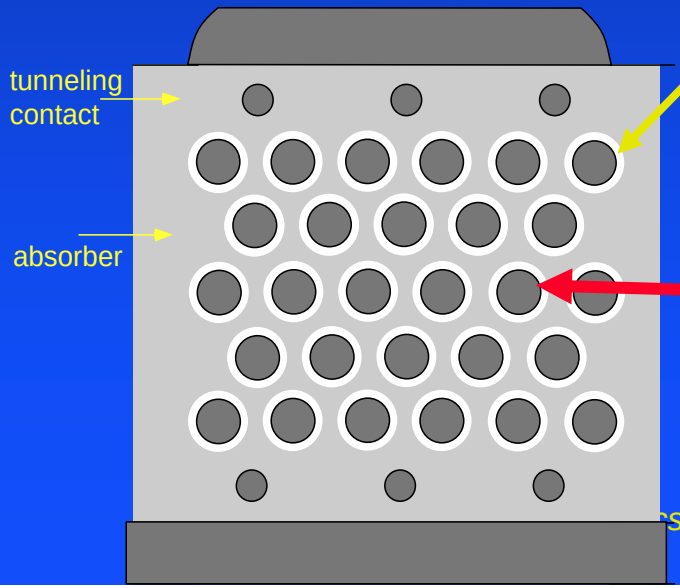


Hot-carrier cell concept

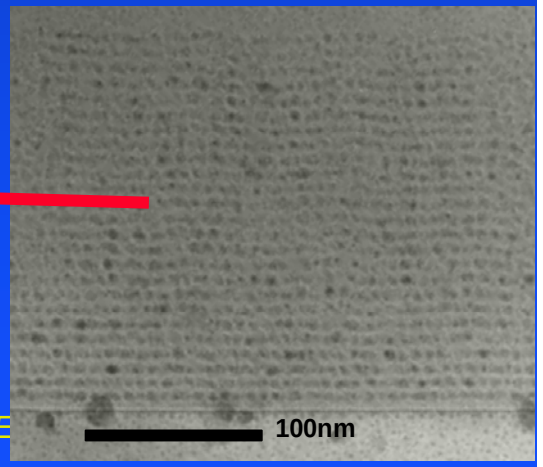


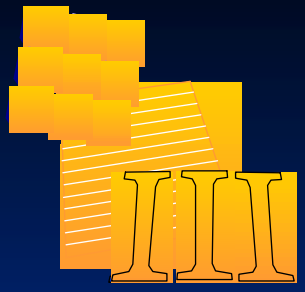
Efficiency > 4 cell tandem





stiff interface





Summary

- *need to fix carbon problem at source*
  - *provide clean, more cost-effective electricity options*
- *photovoltaics provides a solution provided*
  - *volumes increased and costs reduced dramatically*
- *high energy conversion efficiency is the key*
  - *to lowest possible long-term costs*
- *high efficiency thin-film technologies for post-2020 era*
  - *new nano-materials provide increased scope*