Solar Energy Forum

Technology Overview

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A Drought; A Water Crisis

- Once everyone agreed there was a water crisis, we instituted
  - A dedicated body: QLD Water Commission
  - Water restrictions
  - Consumer rebates for tanks, water saving devices
  - Media campaigns
  - New infrastructure

Fastest, cheapest response?

- (Aug 10th) South East Queenslanders subject to Level 5 water restrictions used an average of 133 litres a day last week according to daily water use consumption figures released today.
- Pre-drought usage figures which were … equivalent to 277 litres per person
- 277 litres to 133 litres:

  Residents have ***more than halved*** their consumption.
- The water pipeline grid, new dams and desalination plant are still coming.

QLD Water Commision Media releases Aug 10th and May 11th:
http://www.qwc.qld.gov.au/tiki-index.php?page=Media+releases

NegaWatts, not MegaWatts





Our House

Our electricity consumption

Average daily use (kWh) = 14

	Tariff 11	Tariff 33
This account	11.8	2.3
Account last year	10.8	3.8

Average daily cost (Inc GST) $2.54

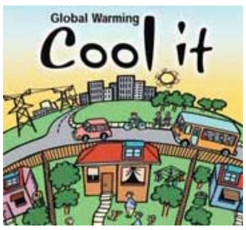
- Built 2005, 4 bed brick & colourbond,
- Open plan, good ventilation, tinted windows, insulation, 4½ star.
- No Solar Hot Water – heat pump instead

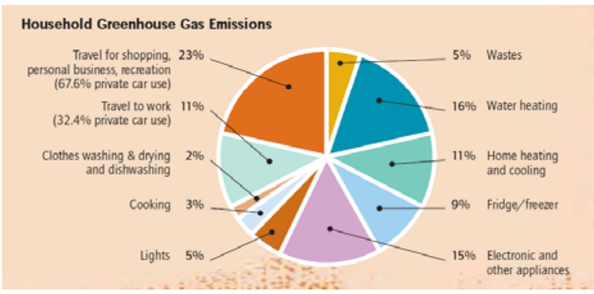
  A compromise, but a good one
- No Solar PV system – green power instead

  $40 per quarter buys1330 kWh > 1274 kWh usage

In summary – we have our cake and eat it too!

Take pride in reducing your Electricity Consumption (and save money too)





- Choose an efficient fridge. Don't run two!
- Beware standby power: If it glows in the dark – then it's using electricity!
- Choose Solar Hot water!
- Minimise Aircon use!
- Choose CFL lights – and turn them off!

http://www.greenhouse.gov.au/gwci/index.html

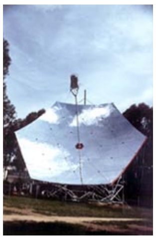
Renewables – the options

- Solar Thermal
- Solar Photovoltaic
- Geothermal
- Biomass
- Wind
- Wave and Tide
- Hydro

These can together completely supply our energy needs without want.

We should choose to shift to these as early and as quickly as possible.

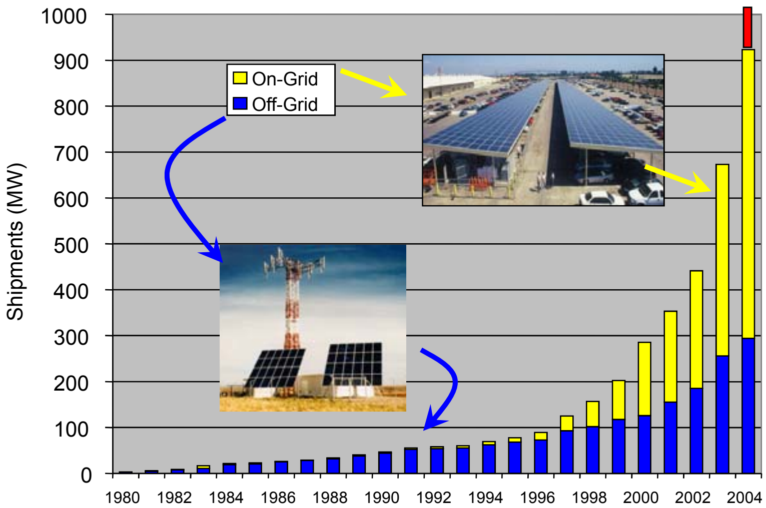
Solar Thermal



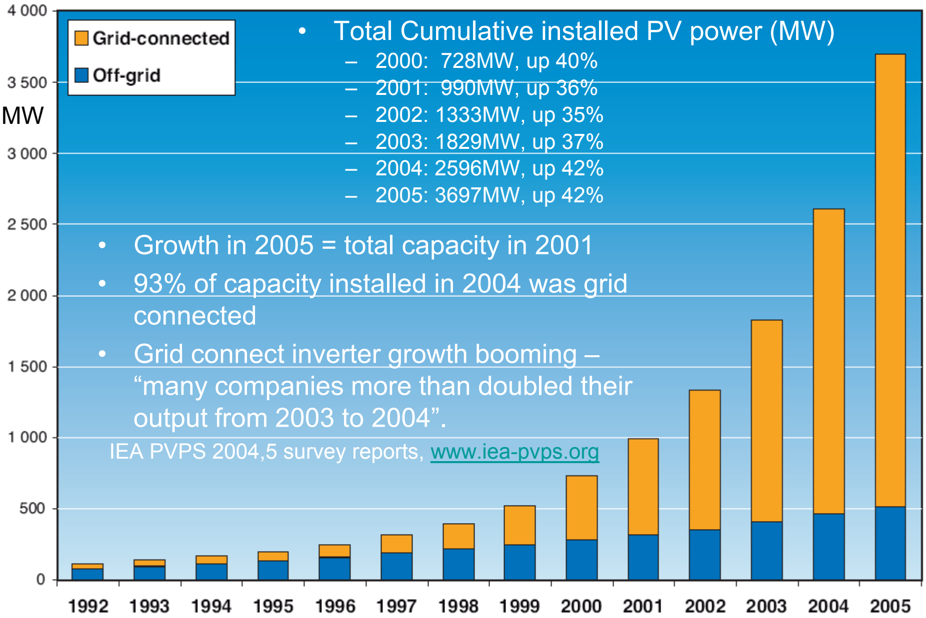
Solar PhotoVoltaic

Photovoltaics (PV) 7 Yr Growth:
Industry: *35%/yr*
On-Grid: *55%/yr*
(slide courtesy of PowerLight)

The worldwide PV market continued its vigorous growth of 30% - 40% per year, passing the 1,000 MW/year production capacity in 2004



Growth of Grid Connected PV



- Total Cumulative installed PV power (MW)
  - 2000: 728MW, up 40%
  - 2001: 990MW, up 36%
  - 2002: 1333MW, up 35%
  - 2003: 1829MW, up 37%
  - 2004: 2596MW, up 42%
  - 2005: 3697MW, up 42%
- Growth in 2005 = total capacity in 2001
- 93% of capacity installed in 2004 was grid connected
- Grid connect inverter growth booming – "many companies more than doubled their output from 2003 to 2004".

IEA PVPS 2004,5 survey reports, www.iea-pvps.org

Where is the growth?

- Germany, Japan, USA
  - This is why there is a worldwide shortage of PV

PV power (MW) installed in calendar year											
Country	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AUS	2,0	3,0	3,0	3,8	2,8	3,9	4,4	5,5	6,5	6,7	8,3
AUT	0,3	0,3	0,5	0,7	0,8	1,2	1,2	4,2	6,5	4,2	3,0
DEU	5,3	10,1	14,0	12,0	15,6	44,3	80,9	83,4	153,0	***363,0***	***635,0***
ESP	0,8	0,4	0,2	0,9	1,1	3,0	3,6	4,8	6,5	10,0	***20,4***
FRA	0,5	1,5	1,7	1,5	1,5	2,2	2,6	3,3	3,9	5,2	7,0
ITA	1,7	0,2	0,7	1,0	0,8	0,5	1,0	2,0	4,0	4,7	6,8
JPN	12,2	16,2	31,7	42,1	75,2	121,6	122,6	184,0	222,8	272,4	289,9
KOR	0,1	0,3	0,4	0,5	0,5	0,5	0,8	0,7	0,6	2,5	6,5
NLD	0,4	0,9	0,7	2,5	2,7	3,6	7,7	5,8	19,6	3,2	1,7
USA	9,0	9,7	11,7	11,9	17,2	21,5	29,0	44,4	63,0	100,8	103,0

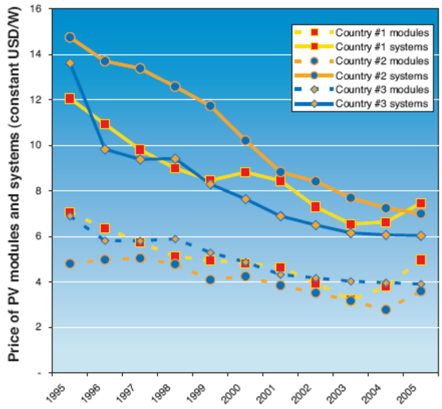
Notes: Countries that are experiencing (or have recorded in a past year) annual market demand of >5 MW
The reader is referred to the German national report for discussion about the agreed installed capacity in calendar year 2004 and subsequent implications for the figures above; the Spanish figure for 2005 reflects the best estimates available at the time of writing

Bavaria Solarpark, Muehlhausen
6.3 MW. World's Largest System

POWERLIGHT
SOLAR ELECTRIC SYSTEMS

Growing production, Falling Prices

- The massive increases in production are leading to falling prices due to the "learning curve".
- In some countries, demand has grown so rapidly that a slight price *rise* has occurred
- Australian prices (2005)
  - Modules: $7 - $8 / W
  - Systems: $9 - $13 / W



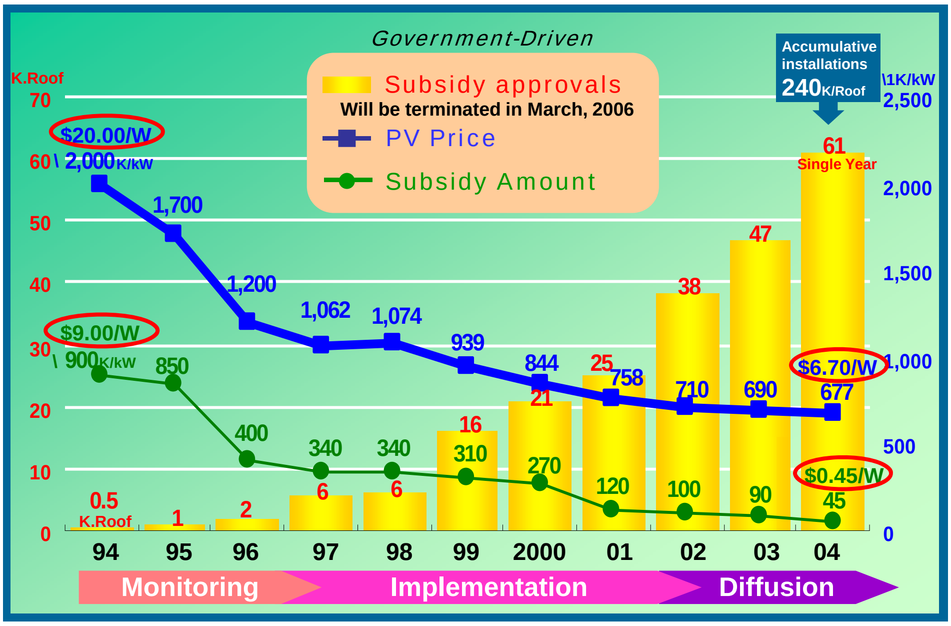
What is happening in Germany and Japan?

Some valuable insights from a paper:

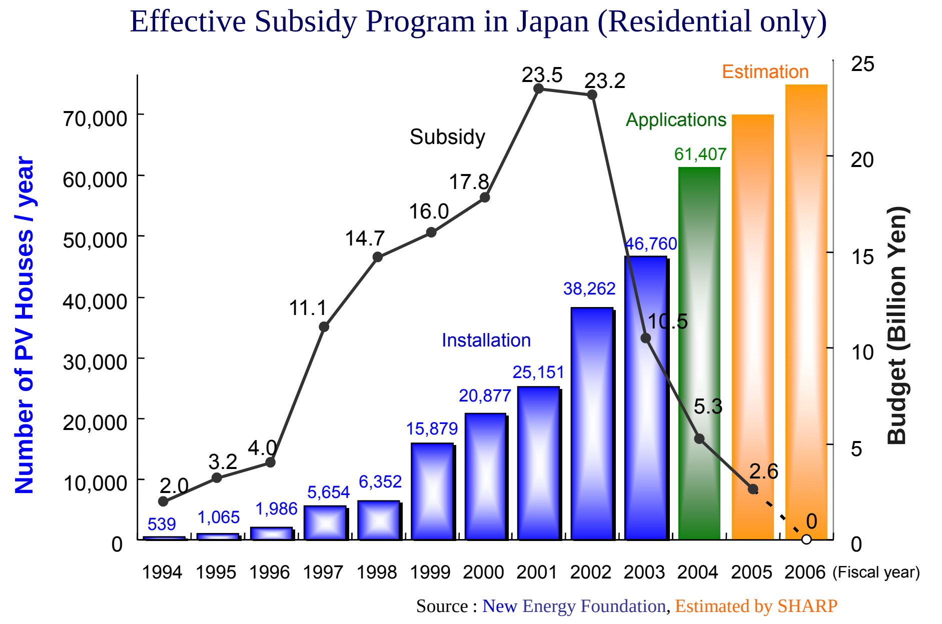
Osborn, D.E., Aitken, D.W., Maycock, P., "**Government Policies to Stimulate Sustainable Development of the PV Industry: Lessons Learned from Japan, Germany and California**", 2005 Solar World Congress, Orlando, Florida, August, 2005.

Many thanks to the authors for sharing their slides

ROOF TOP STORY IN JAPAN



New demands are increasing without depending on subsidies



Summary of Japanese PV Program Accomplishments:

- Installation of over 1000MW
- Installation of 3.5kW PV systems in over 200,000 homes
- 2004 shipments of over 600MW with 300MW installed in Japan and 300MW exported.
- Reduced costs to make PV economic without subsidy.
- Creation, by the housing industry, of zero energy houses using renewable energy for electricity.

Sustained, Orderly Development & Commercialization

✓***Sustained***

✓***Orderly***

✓***Substantial***

✓***Predictable***

✓***Credible***

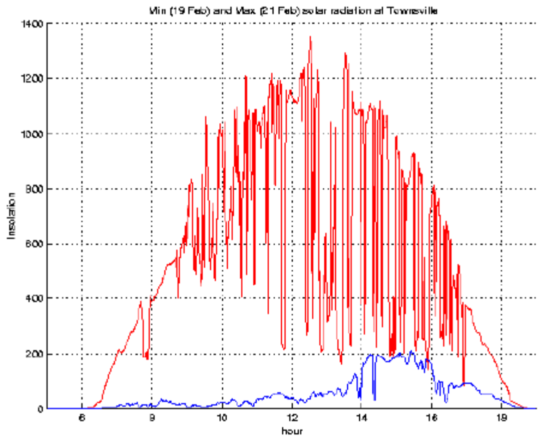
✓ ***Ramped***

Government policies to stimulate sustainable development of the PV industry: lessons learned from Germany, Japan, and California
Osborn, Aitken, Maycock, ISES Solar World Congress 2005

The Power of the Sun

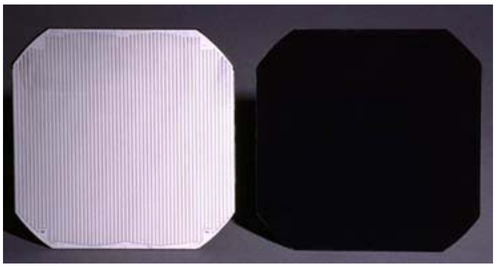
- Insolation is the measure of solar radiation energy incident on a surface.
- Sun's insolation on the earth's surface measured in Watts / sq metre
- 1000 W / m2 = 1 "Sun".
- Varies as a sinusoid (roughly) from dawn to dusk, peaking at about 1.2 Suns.

Solar radiation Townsville, Feb 1991
Min (Feb 19) and Max (Feb 21)



Anatomy of a PV system

- PV cell 100, 125 or 150mm square, 0.3mm thick
  - 0.5V, 4A, 2W under full sun
  - Brittle, fragile
  - Monocrystaline, polycrystaline



Anatomy of a PV system

- PV module = 36 (or 72) cells connected in series
  - 15 - 20V (35 - 45V) and 4A - 5A = 80 to 210W
  - Mounted underneath toughened 3mm glass
  - Sealed in behind a waterproof membrane
  - Usually framed by aluminium frame
  - Will withstand a golfball sized hailstone at terminal velocity.
  - 10 year warranty
  - 25+ year life

Anatomy of a PV system

- PV array = several PV modules connected in series
  - For example a 1000W (1kW) array
    = 6 * 170W modules connected in series

  216V, 4.7A = 1020W

Anatomy of a PV system

- PV grid connected systems = PV array connected to a dc-ac inverter, connected to the 240Vac electricity grid.
- Grid connect inverter converts 200V 5A dc to 240V ac,
- Keeps the PV modules at their Maximum Power Point (MPP)
- Ensures safety

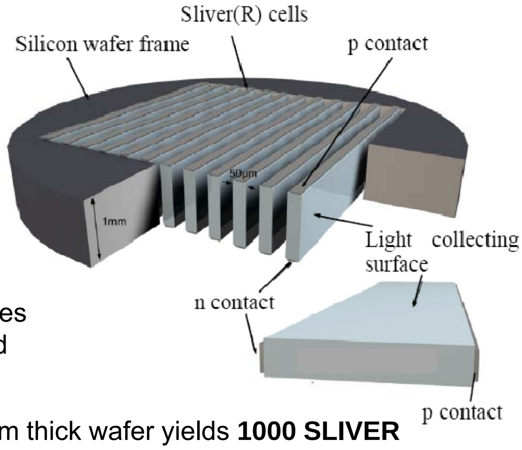
PV Research in Australia

- Sliver cells
  - ANU, now Origin Energy
- Crystalline Silicon on Glass (CSG)
  - UNSW, now CSGsolar
- Dye Sensitised Cell (DSC)
  - Sustainable Technologies International, STI
- Antireflective coating for all PV
  - UQ, now XeroCoat

Australian PV – Sliver Cells

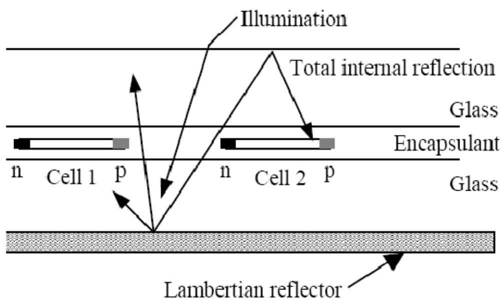
- Developed at ANU
- Commercialised by Origin energy

Sliver Cell Manufacture



- Each sliver is about
  - 100mm long,
  - 1.5mm wide
  - 50µm thick.
- Made by etching deep grooves through a conventional round silicon wafer
- Each 150mm diameter 1.5mm thick wafer yields **1000 SLIVER solar cells** with a combined surface **area of about 1,500 cm^2**
- Conventional solar cell fabricated using the wafer would have area of 177cm^2
- This is an **EIGHT-fold gain**, still with excellent efficiency and conventional processing techniques

Sliver cell Module manufacture



- Both sides of the sliver cells are active – Bifacial
- By encapsulating the cells between two panes of glass and using total internal reflection …
- Cell spacing / Cell usage / Energy produced

Cell spacing	Cell usage	Energy produced
100%	100%	100%
50%	50%	79%
33%	33%	62%

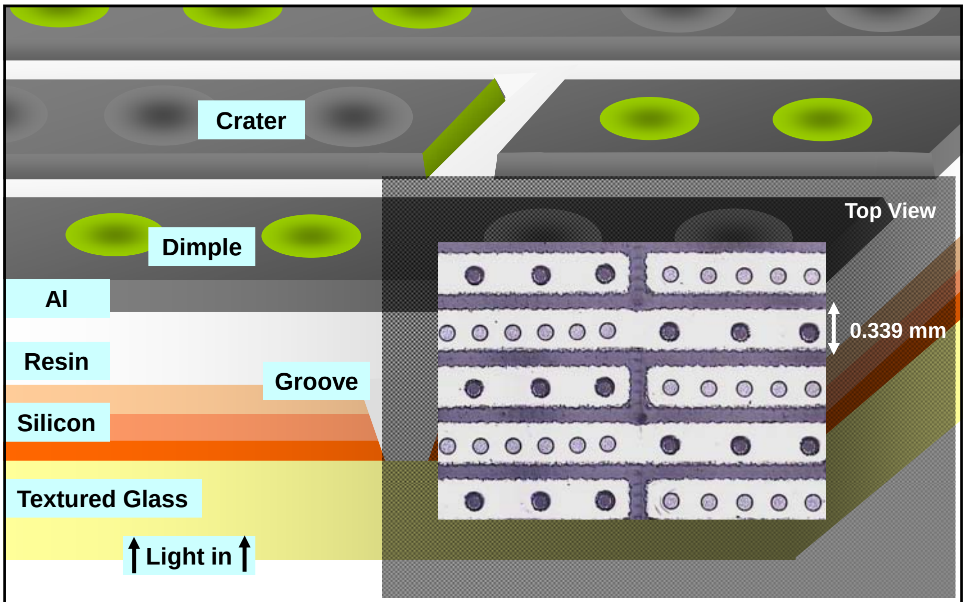
- Combining these techniques, 2 cells are sufficient to manufacture a PV module equivalent to a conventional 36 cell module – Result: cheaper modules.

Crystalline Silicon on Glass – CSG Solar

- Developed at UNSW
- Factory - Germany
- R&D Pilot Line – Sydney
- Places Silicon “film” directly on glass – borrowing processes from Plasma screen manufacture.
- Lower efficiency, at lower cost – lower $/W

CSG manufacturing process

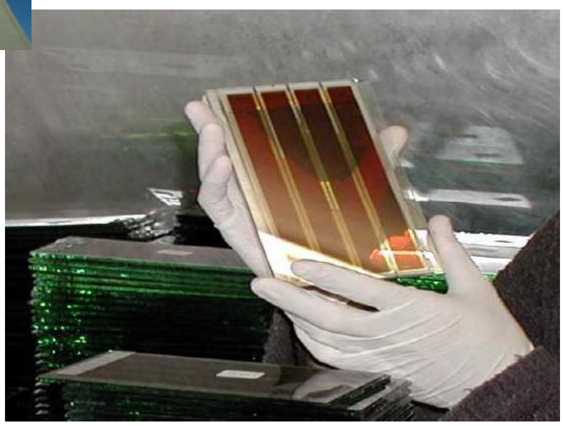
- A very thin layer of silicon (<2μm) is deposited directly onto a glass sheet
- The silicon is crystallised by heating in an oven.
- This layer is processed using lasers and ink-jet printing techniques to form the electrical contacts on the thin silicon film.
- The crystalline nature of the silicon film ensures that it will last for decades even when exposed daily to bright sunlight in a harsh environment.



Completed CSG Structure

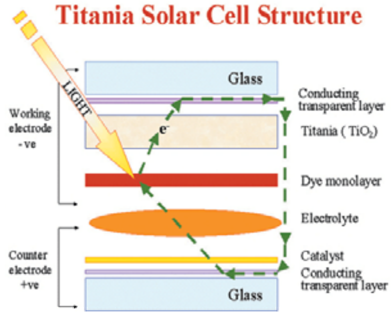
Sustainable Technologies International
Dye Sensitised Cell (DSC)

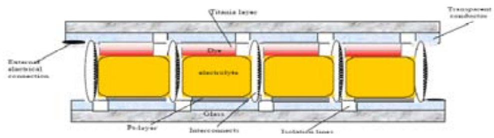
- Developed at STI from Swiss concept



Sustainable Technologies International Dye Sensitised Cell (DSC)

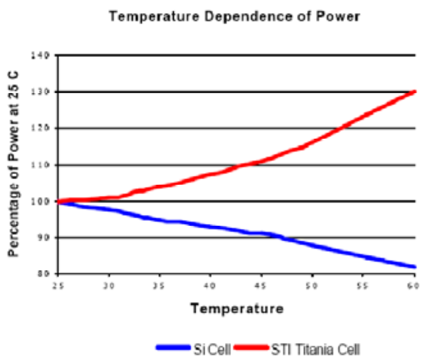
- Operates like an electrochemical cell in a process likened to photosynthesis
- Breakthrough was use of nano particles
- Manufacturing process low cost, low temperature

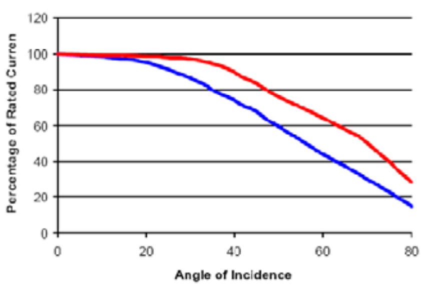




Unique advantages

- DSC performance improves
  - as temperature rises
  - at low light levels
  - for oblique light
- Suited for building integrated panels in the topics



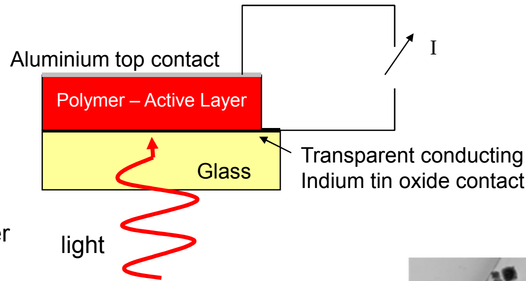


UQ research – Plastic Solar Cells

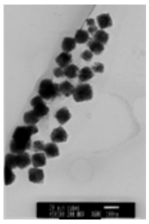
η_{UQ} = 1%, η_{WR} =5%

Solutions of nanocrystals blended into a conducting polymer

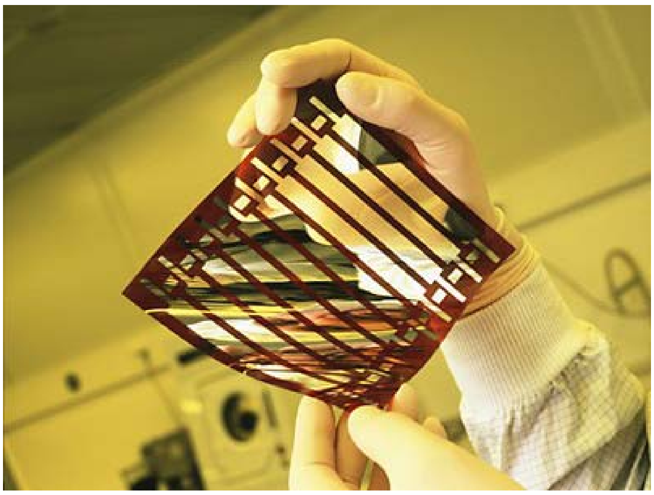
A conducting polymer: inorganic nanocrystal "bulk heterojunction plastic solar cell"



1. Thin polymer film applied as a liquid
2. Photons absorbed by the polymer
3. Electrons and holes separated at the polymer: nanocrystal interface
4. Electrons travel through nanocrystal network to one electrode
5. Holes travel through polymer network to other electrode



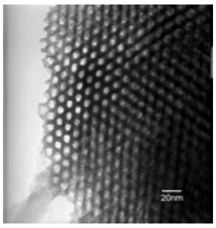
UQ Plastic Solar Cells



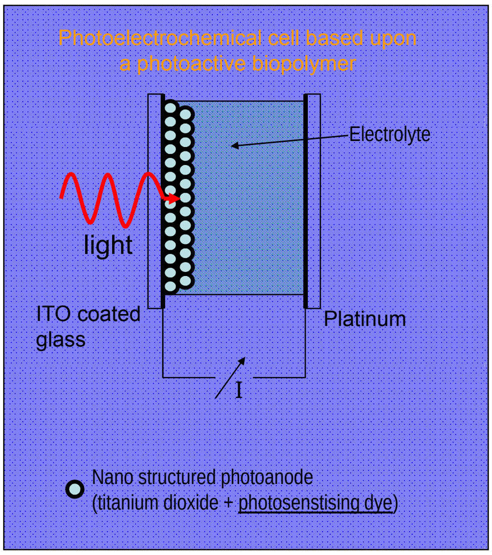
Photoelectrochemical solar cells

1. Nanostructuring = large surface area
2. Titania nanoparticles – dye coated
3. Dye absorbs photon
4. Electron injected into titania
5. Electrolyte completes the circuit
6. Cheap, easy to manufacture

$\eta_{UQ} = 4\%, \eta_{WR} = 11\%$

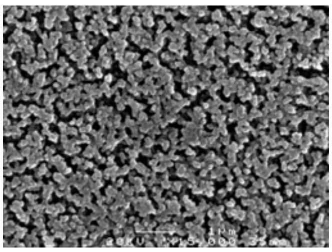


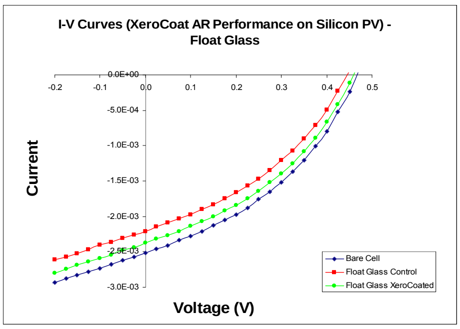
Nanostructured titania



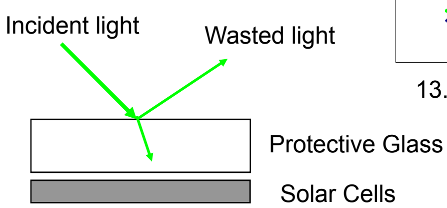
UQ developed XeroCoat: Better Efficiencies NOW

XeroCoat: a (cheap) nanoporous silica coating that eliminates unwanted reflections





13.5% relative efficiency improvement

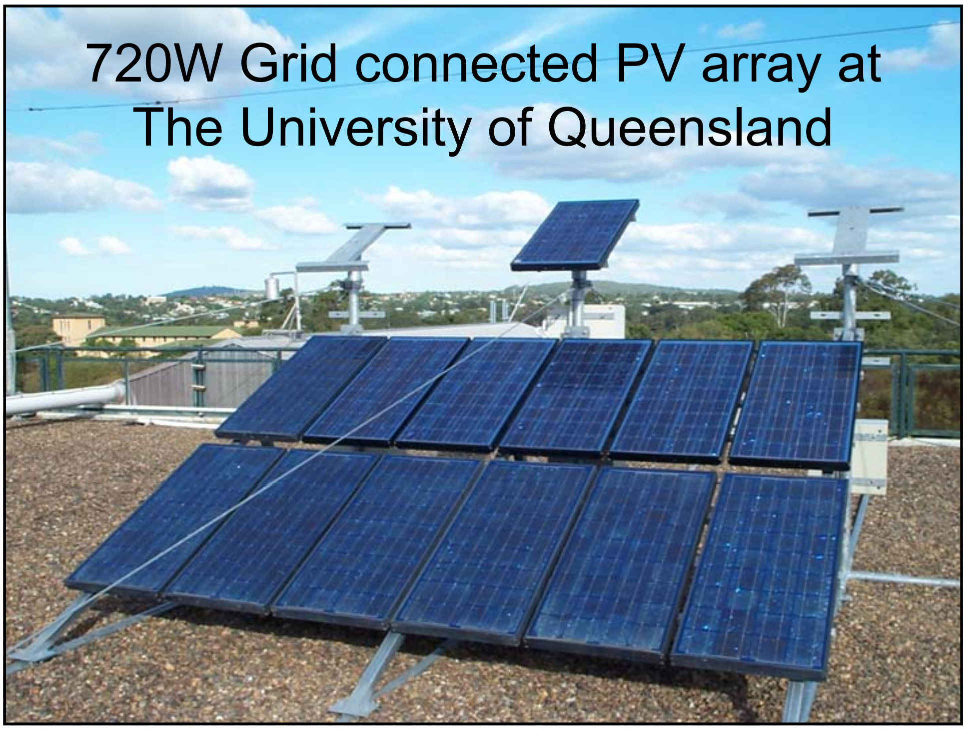


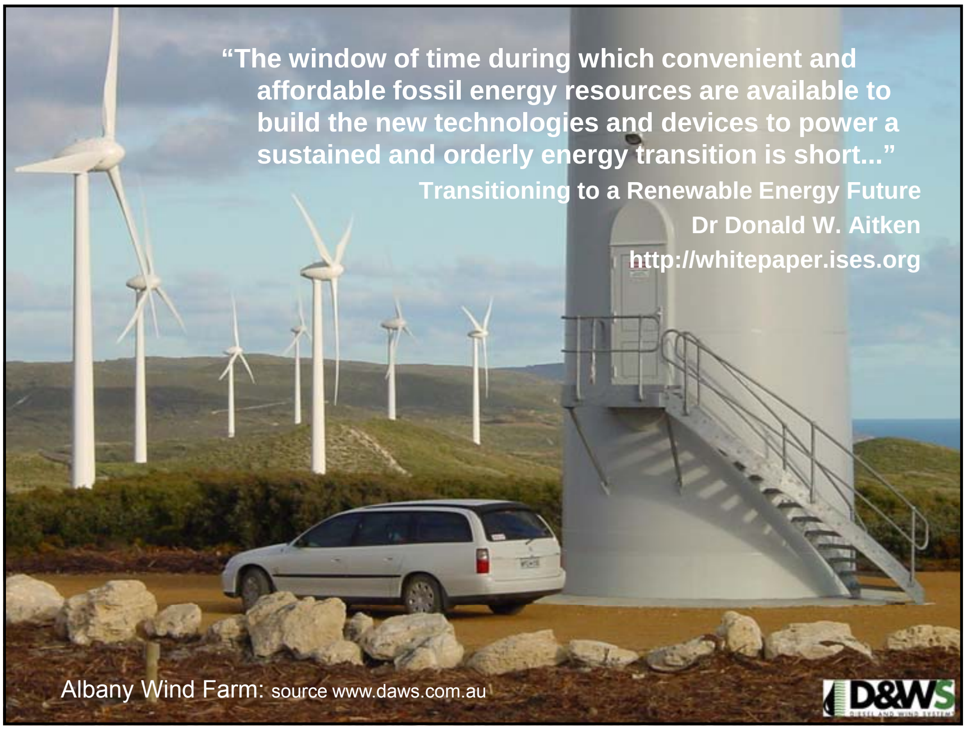
My work: looking at PV strings and Grid connect Inverters

- Series PV strings are forced to carry the same current
- Shading or orientation can mean some PV modules forfeit power
- Intelligent power electronic converters on each PV module "capture" this lost power

PESC June 2006 p.41

720W Grid connected PV array at The University of Queensland




"The window of time during which convenient and affordable fossil energy resources are available to build the new technologies and devices to power a sustained and orderly energy transition is short..."
Transitioning to a Renewable Energy Future
Dr Donald W. Aitken
http://whitepaper.ises.org
Albany Wind Farm: source www.daws.com.au
D&WS