Nuclear Energy and Nuclear Weapon Proliferation: A New Perspective

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Summary

- Joseph Rotblats' view of the civil/military nuclear links in 1979
- UK Nuclear power and the Energy Review 2006
- UK Civil/military nuclear links 1979 – 2006
- The NPT, Iran and North Korea 2006
- General discussion of the civil/military link

Nuclear Energy and Nuclear Weapon Proliferation – J.Rotblat 1979

- "The peaceful and military aspects of nuclear energy are intrinsically linked and it is impossible to separate them"
- Concern about the Non-Proliferation Treaty (NPT):-
  - the NW states were NOT pursuing "negotiations in good faith" to halt the nuclear arms race.
  - states party to the treaty can withdraw from it giving three months notice
- IAEA – concern that its promotional and safeguard activities were "contradictory" and the former pursued more vigorously
- He proposed setting up a "World Energy Agency" to promote and research non-nuclear alternative energy utilization.

The World Changed in 2001

- UK reactors and waste facilities are potential terrorist targets.
- "No reactors have been designed specifically to withstand the impact of a large commercial aircraft " [1]
- At best protection was designed to withstand the impact of a light aircraft
- Release from Sellafield of < 1% of the Pu in a smoke plume could require evacuation of an area extending to Newcastle [2]

1. Parliamentary Office of Science and Technology, Report 222, July 2004

2. Frank Barnaby, Evidence to the Commons Defence Committee, July 2002

Nuclear Waste

- Waste clean-up £2B/yr
  £48B (2002) => £56B (2005) => £70B (2006) [1]
  = over £30x per head per year for over 30 years
  Would any other industry with this record
  be given a second chance?
- The waste must be kept out of the environment and out of the hands of terrorists for ~ 1M years
- There is still no method of long term storage that is scientifically and publicly acceptable

1. J.Nisse, Independent on Sunday, 2-04-2006

Nuclear Costs

- Nuclear power cost estimates have always been unrealistically optimistic since the days of “electricity too cheap to meter”
- Many pro-nuclear assessments of capital costs including decommissioning and waste ~ £1/W
- But AGR decommissioning [1] ~ £2/W
- Waste clean-up £70B (2006) [1] => ~ £5/W
- It is generally accepted the government will have to fund the insurance, security, decommissioning and waste treatment and long term storage costs – but how much?

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1. J.Nisse, Independent on Sunday, 2-04-2006

Nuclear is not a Carbon-Free Technology

- Electricity needed to mine ore, refine ore, enrich U, build reactor, store waste…..
- As lower concentration ores mined more electricity may be needed to extract the U than the reactor will produce

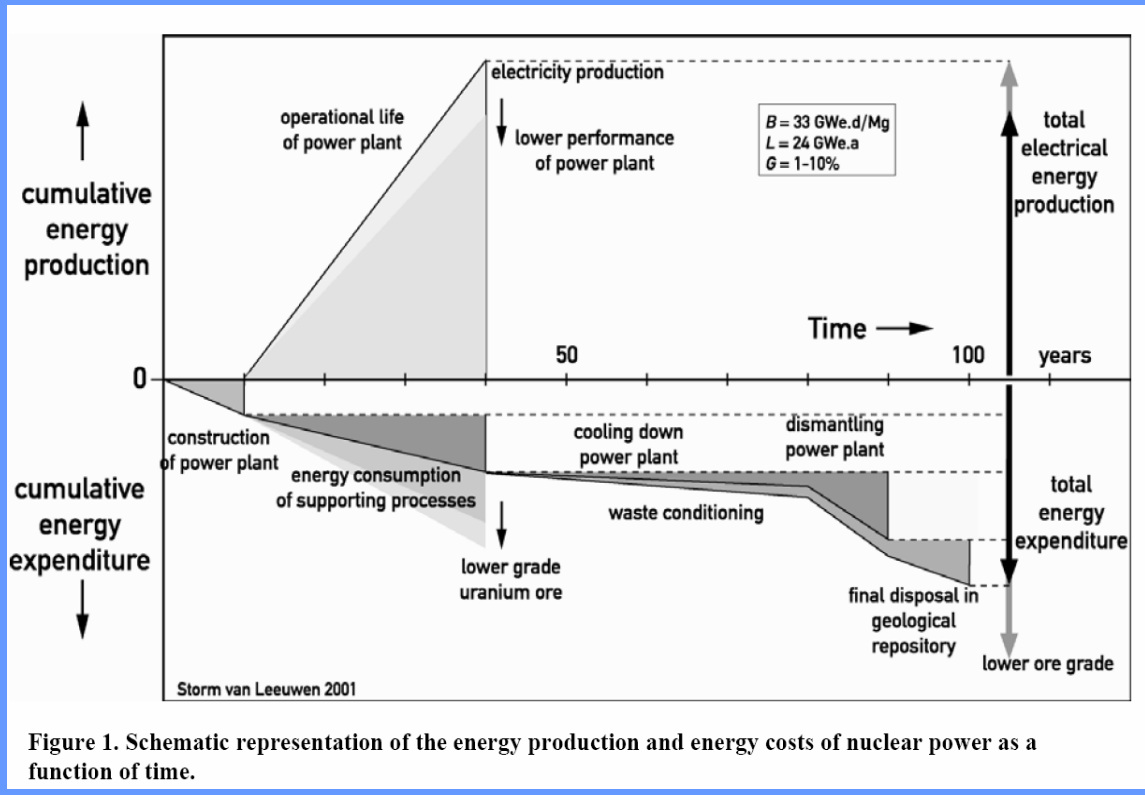


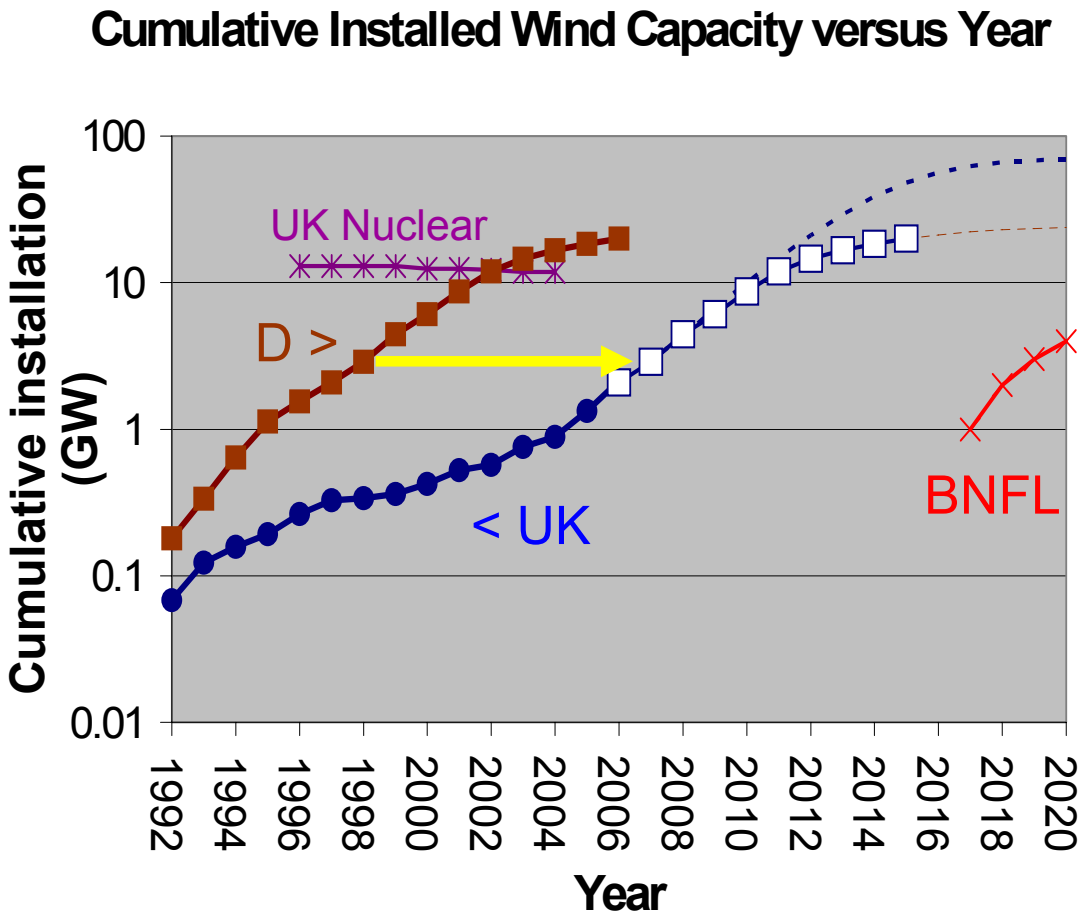
Figure 1. Schematic representation of the energy production and energy costs of nuclear power as a function of time.

Rotblat:
1 year PWR fuel ~ 28 te U
Enrichment plant ~ 181 te U
Need to mine ~ 10^5 te ore

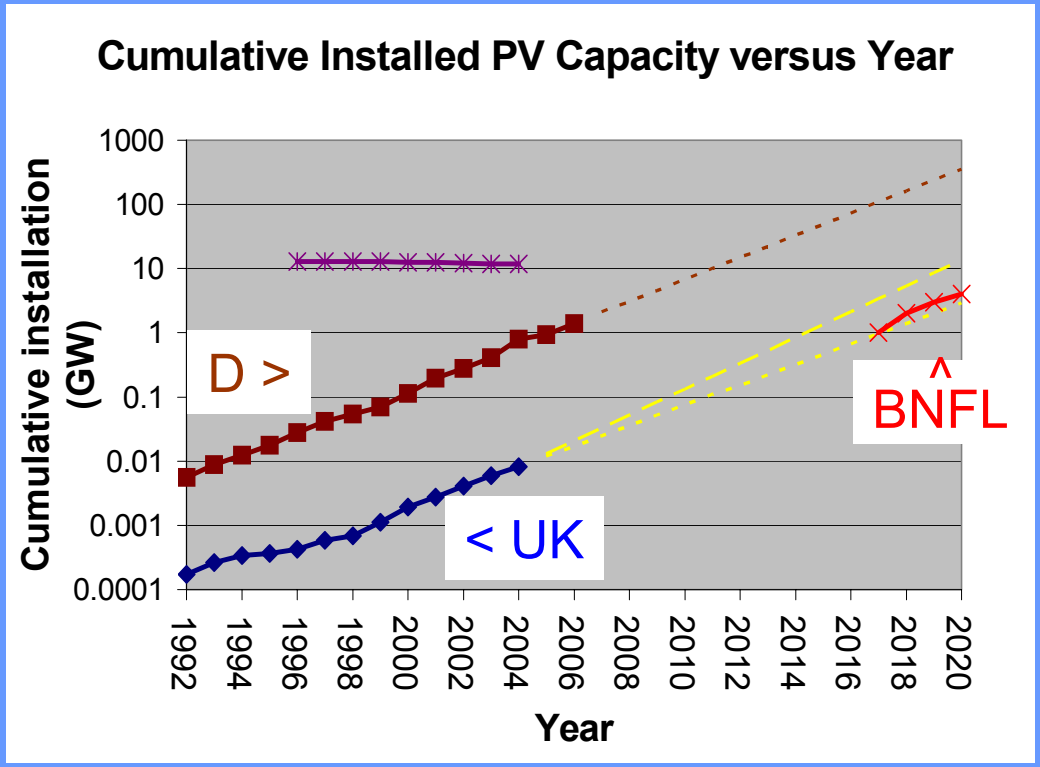
J.W. Storm van Leeuwen and P. Smith, http://www.stormsmith.nl/ (Jan 2006).

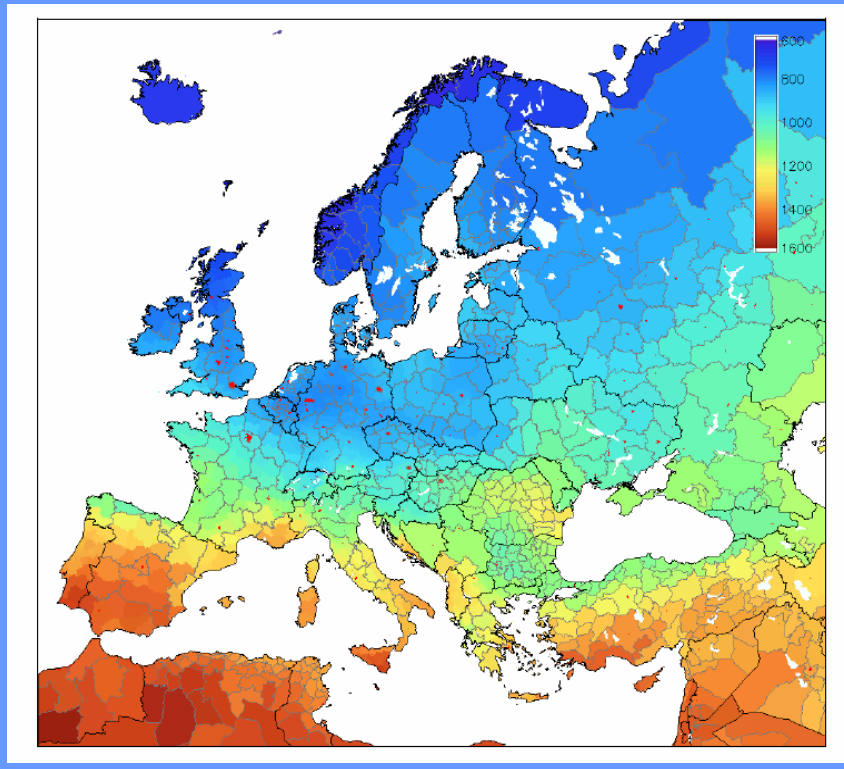
Cumulative Windpower Capacity Germany and UK

- Germany had more wind capacity than UK nuclear by 2002
- If in the next 9 years the UK follows the last 9 nine years of the German trend the UK will have more wind than our current nuclear by 2012



Cumulative Photovoltaic Capacity Germany and UK





If Germany continues trend of last 12 years => 12 GW by 2012
If UK follows German trend of last 4 years => 12 GW by 2020

K.W.J.Barnham, M.Mazzer, B.Clive, Nature Materials, 5, 161 (2006)

Smart Windows - Concentrators for Building Integration

- (400 – 1000)x concentration
- Transparent modules
- ~ 1 mm solar cells
- Cell efficiency ~ 30%
- novel 1.5 and 2-axis tracking
- adds ~ 20% to façade cost

Unique advantages:

- No transmission of direct sunlight
- Reduce a/c requirements
- Max diffuse sunlight - for illuminatio
- (2 – 3) x power from Silicon BIPV
- Provide electricity at peak times
- Cell cooling provides hot water

Civil Nuclear Summary 2006

- Nuclear facilities are potential terrorist targets
- Waste problem has yet to be solved
- Secure waste storage will require massive government support for decades
- The CO_2 emissions may not be small after all
- Renewables are delivering - more quickly and they are more popular

So why has the PM decided we must have nuclear?

UK Civil/Military Nuclear Links 1979 - 1986

- 1960s Civil Magnox reactors designed to produce Pu for weapons
- 1981 Details of 1958 Mutual Defense Agreements (MDA) US/UK made public. UK civil plutonium exchanged for military HEU and tritium ~ 1970
- 1983 "No Pu produced in any of the CEGB's nuclear power stations has ever been used for military purposes[1]…"
- 1984 Sizewell Inquiry – UK civil and military Pu still being "co-processed"
- 1985 Barnham, Hart, Nelson and Stevens (BHNS) publish only public estimates for Pu production in UK civil Magnox reactors[2]
- 1986 "No Pu produced in civil reactors, in this country has been transferred to defence use…..during the period of this administration[2]"

1. *Hansard, 4-2-83, Col. 206*
2. *Barnham, Hart, Nelson and Stevens, **Nature**, **317**, 213, (1985)*
3. *Hansard, 15-4-86, Col. 330*

UK Civil/Military Nuclear Links 1988
Comparisons after model published (I)

Pu in spent fuel and in core 1983 -1987
Total all civil Magnox reactors

K.W.J.Barnham, D.Hart, J.Nelson, R.A.Stevens, Nature ***333****, 709, (1988)*

	BHNS te	Parliamentary Answers kg (to nearest 0.5 te)	Percentage Difference %
Discharged 1st April 1983 - 31st March 86	7.37	7.5	-1.7
In core 31st March 86	9.71	9.5	+2.2
Discharged 1st April 1983 - 31st March 87	9.68	9.5	+1.9
In core 31st March 87	10.09	10.0	+0.9

UK Civil/Military Nuclear Links 1988
Comparisons after model published (II)

- Pu in spent fuel discharged in year 1986 -1987 for civil Magnox reactors[1]
- Sizewell Inquiry recommended Pu figures published
  - rounding 50 kg.
- After Hinkley Pt Inquiry
  - rounding 5 kg
- Publication stopped in 1998[2]

Station	BHNS kg (to nearest 5 kg)	Parliamentary Answers kg (to nearest 50 kg)
Bradwell	160	150
Berkeley	100	100
Hinkley PtA	350	350
Trawsfynydd	245	250
Dungeness A	195	200
Sizewell A	200	200
Oldbury	285	250
Wylfa	170	150
Hunterston A	220	200

*1. Barnham, Hart,.Nelson, Stevens, Nature **333**, 709, (1988)*
*2. Barnham, Nelson, Stevens, Nature **395**, 793, (1998)*

UK Civil/Military Nuclear Links 1988 -1996
Pu Export to US under MDA

- Only a subtotal of the civil Pu appears in official figures as the balance was sent to the US under the Mutual Defense Agreement
- 1985 BHNS estimate balance = (6.3 +/- 0.8) te
- 1986 RAWMAC[1] Pu in solid waste 1.75 te
- 1992 Barnham[2] revised balance = (5.4 +/-0.8) te
- 1996 US Dept of Energy[3] MDA = 5.4 te

1) *RAWMAC 7th Annual Report (London, HMSO, 1986)*
2) *Keith Barnham, "Plutonium and Security", ed. F.Barnaby, Macmillan, 1992*
3) *Plutonium: The First 50 Years (US Dept. of Energy, Feb. 1996)*

Testing Pu from Military Reactors

- Calder Hall and Chapel Cross refuel off-load.
- Spent fuel discharges and refuelling regime have not been published. Hence do not have all data required for modelling

Data 1) – Pu versus burn-up published for Calder Hall

Data 2) - military cycle finished end 1965? Total thermal energy.

Data 3) assume reactor fully re-loaded when 7% Pu 240

- 1987 (BHNS unpub.) Calculate weapons grade Pu = 3.3 te
- 2000 MoD Weapons grade total "available" = 3.2 te

(Windscale[1] 0.4 te = Tests[2] + U.S.[3] + reprocessing loss[,4,5] = 0.4 te)

1) *D.Albright et al. "World Inventory of Pu…" SIPRI, (1992)*
2) *MoD, "Plutonium and Aldermaston: an historical account" (2000)*
3) *US Dept of Energy "DOE FACTS", (1996)*
4) *MoD "Historical Accounting and Plutonium",(2000)*
5) *Keith Barnham, "Plutonium and Security", ed. F.Barnaby, Macmillan, 1992*

2) the BHNS analysis identified the source?

UK Civil/Military Nuclear Links 1996 -2000

- 1985 BHNS civil weapons grade Pu (0.36 ± 0.11) te. None in civil stockpile [1]
- 2000 MOD "figures show that the weapon cycle stockpile is in fact some 0.3 te larger than the amount of plutonium the records indicate as available[5]" [2]
- 2000 MoD "From Unidentified Sites, 0.37 te" [3]

=> 11% of Pu in UK warheads came from civil reactors

1. *Hansard 27-7-83, col 439*
2. *MoD www.fas.org/news/uk000414-uk3.htm (2000)*
3. *Barnham, Nelson and Stevens, **Nature**, 407, 833, (2000)*

UK Civil/Military Nuclear Links 2000 -2005

- 2000 In the 1980's 1000s of tonnes of depleted U were removed from the safeguarded civil programme for munitions and armour used in both Gulf wars and for tritium production for nuclear warheads [1]
- 2004 MDA renewed – details secret
- 2005 MoD announces spends £79M/year on "nuclear related research" [2]

1 "Withdrawals from Safeguards....." Dep. 00/1261 (July 2000), HoC Library
2 Hansard Vol. 440, Part 84, Column 2041W (14 December 2005); <http://www.publications.parliament.uk/>

Problems with the NPT 2006

- Each NWS agrees “not to transfer to *any recipient whatsoever* nuclear weapons....or control over such weapons….directly or indirectly....”
- Trident is not *independent* – cannot be fired without US say so [1]
- The UK/US MDAs governing Polaris, Trident and Trident replacement are violations of the NPT?
- The UK and US supply of nuclear material and know-how to Israel are violations of the NPT? [2]
- UK has mixed its civil/military Pu activities
- UK and has withdrawn significant amounts of material from safeguards for use in nuclear (and non-nuclear) weapons

1. *Dan Plesch, New Statesman, 27-3-2006*
2. *Richard Norton-Taylor, Guardian, 10-3-2006*

The Problem of North Korea

- North Korea signed the NPT, developed Pu reprocessing as part of a civil programme and then withdrew from safeguards as Rotblat forewarned
- Could the diversion have been detected earlier were details of refuelling, discharge and energy generated made public as part of a Fissile Material Cut of Treaty?

The Problem of Iran

- Iran has abundant solar and wind resources and is earthquake prone – it is clear Iran has no pressing need for a *civil* nuclear programme in 2006. It has signed the NPT
- Iran has a near neighbour (Israel) who has nuclear weapons gained with help from US/UK [1]
- Iran has a neighbour (Iraq) who has signed the NPT who, nevertheless, had a nuclear reactor destroyed by Israel, a country that has not signed the NPT.
- Iraq, who doesn't have nuclear weapons, has been invaded by the UK and US and the now littered with depleted uranium withdrawn from IAEA safeguards.
- Can the UK hope to persuade Iran to adhere to the NPT?

1. Richard Norton-Taylor, Guardian, 10-3-06

General discussion of the civil/military link

- Is the military link a reason why the PM has gone for new build?
- 2010 NPT review conference should *add* to article IV

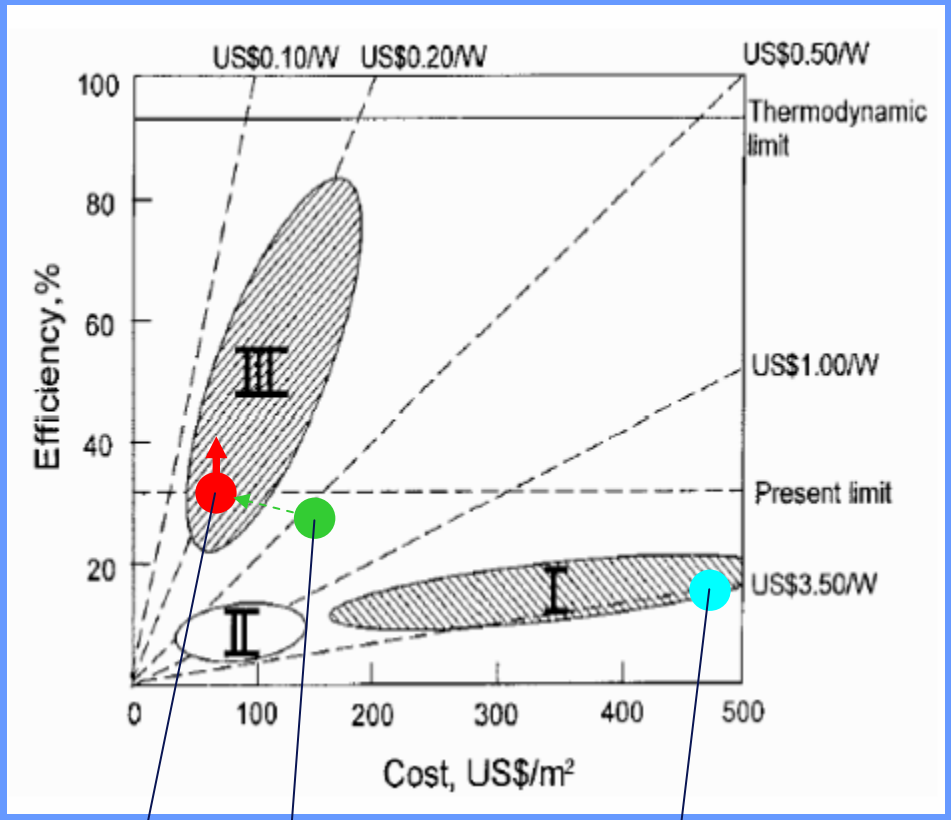
  "co-operate on promoting all renewable energies"
- Start Rotblat's "World Energy Agency" funded more than IAEA
- The UK should take a lead in the context of a fissile material cut off treaty and publish full details related to Pu production in civil and military reactors.
- The MoD, should clarify how *control* of the Trident replacement will work, explain any links to the decision on new civil nuclear build and its support for R&D

  (submarine reactors, fuel, tritium replacement, expertise?)

  and explain how all these are consistent with the NPT

The Three Generations of PV

- First Generation
  - ➔ Crystalline and poly-crystalline Si
    ~ $3/$W_p$
- Second Generation
  - ➔ Thin film cells CdTe, $CuInSe_2$
  - ➔ <15% effic., ~ $(1-2)/$W_p$
- **Third Generation**
  - ➔ III-V cells
  - ➔ (400-1000)x concentration
    ~30% +, <$1/$W_p$.



M.A.Green, "*Photovoltaics for the 21st Century II*", Electrochemical Soc. Proc. Vol. **2001-10**, 1, (2001).

Our Target (1000x)

Our Present State (400x)

Silicon - no concentration

First Generation cells in BIPV

Cell Efficiency
~ 15%

http://www.pvsystem.net/

Shibuya, Japan
The First BIPV Building in Japan

Where, when and why do we use Electricity?

Where?

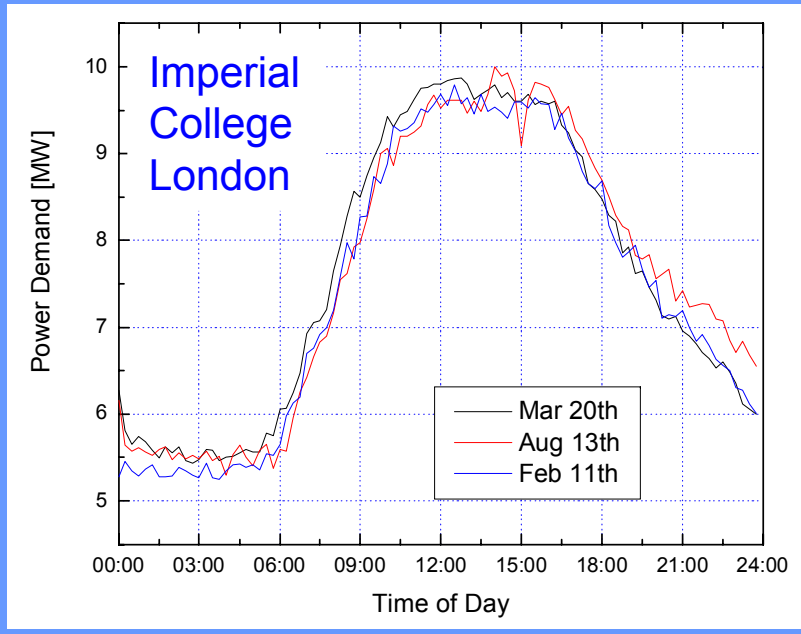
- 63% of electricity in UK used in buildings
- Sunlight on buildings ~ 7x electricity consumption in the buildings
- 14% efficient 2nd Generation cells on all S-facing walls => 3x nuclear contribution

When?

- Peak similar throughout year ~2x baseload due to electrical equipment in use during the day

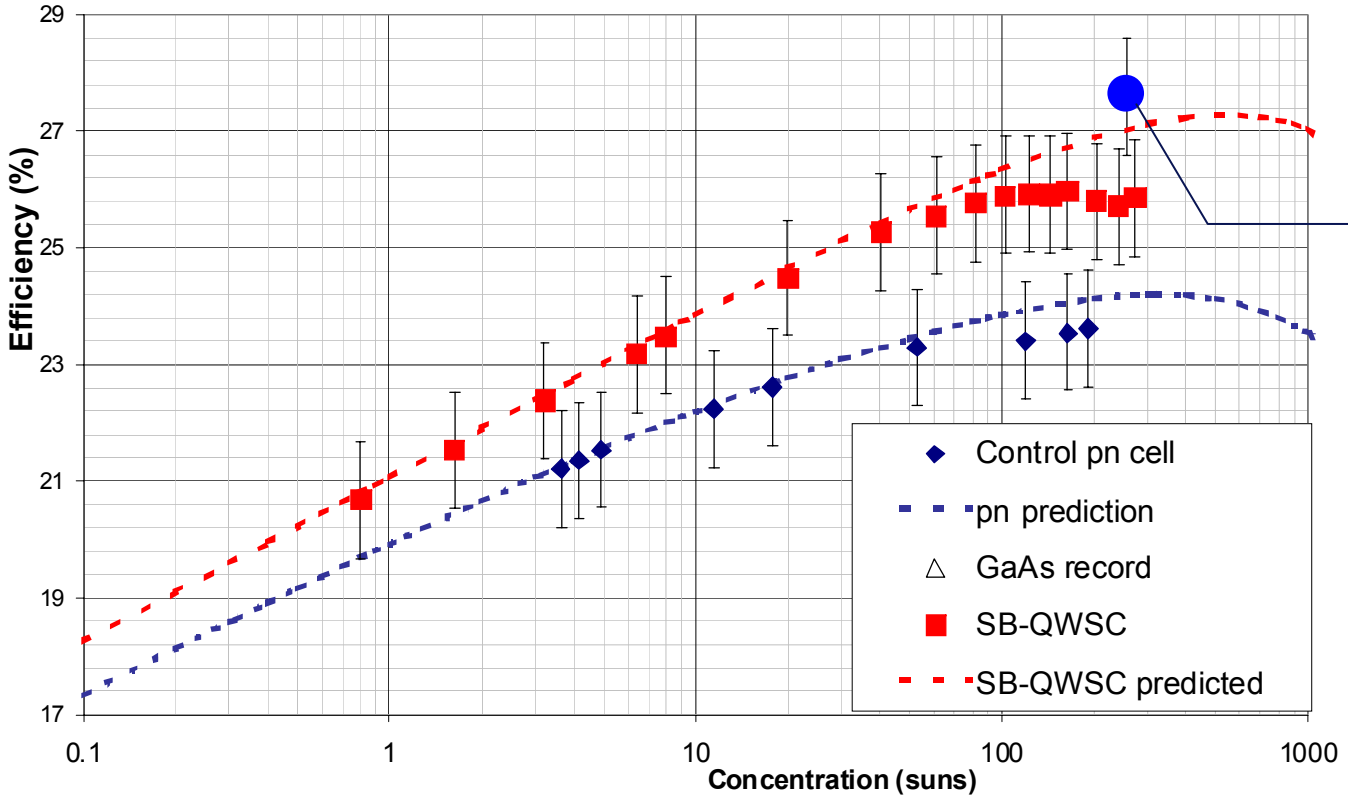
Why?

- Air-conditioning, refrigeration follow the sun.
- Air-conditioning demand in EU increasing at 17% a year

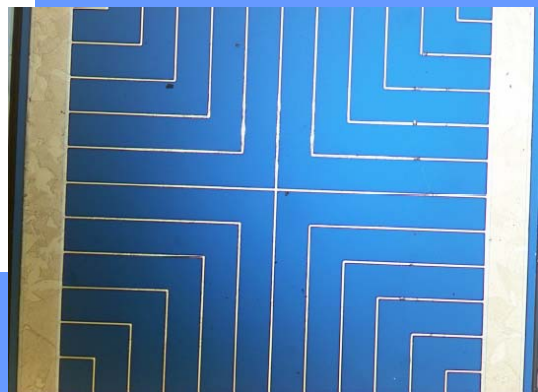


SB-QWSC Efficiency vs. Concentration

- 50 well SB-QWSC ~ 2% higher efficiency than p-n control
- 65 well cell should achieve World record at 500x

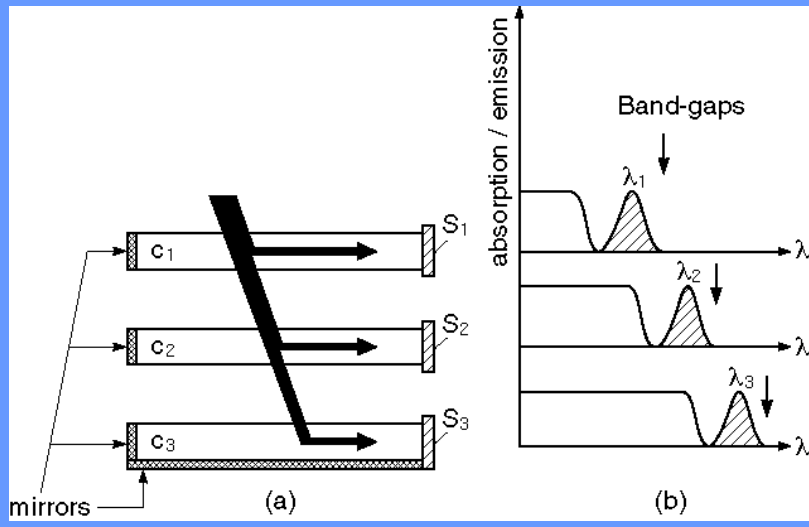


Single Junction Cell World Record



Quantum Dot Concentrator

- QDs replace dyes in luminescent concentrators:
  - ➔ QDs degrade less in sunlight
  - ➔ core/shell dots high QE
  - ➔ absorption edge tuned by dot size
  - ➔ absorption continuous to short λ
  - ➔ red-shift tuned by spread in dot size
  - ➔ spread fixed by growth conditions
  - ➔ secondaries/homogenisers in Smart Windows



(K.Barnham et al. App. Phys.Lett.,75,4195,(2000))

The energy Review

- http://www.dti.gov.uk/energy/review/