



Solar Photovoltaics in India

Rangan Banerjee

Department of Energy Science and Engineering
Indian Institute of Technology Bombay



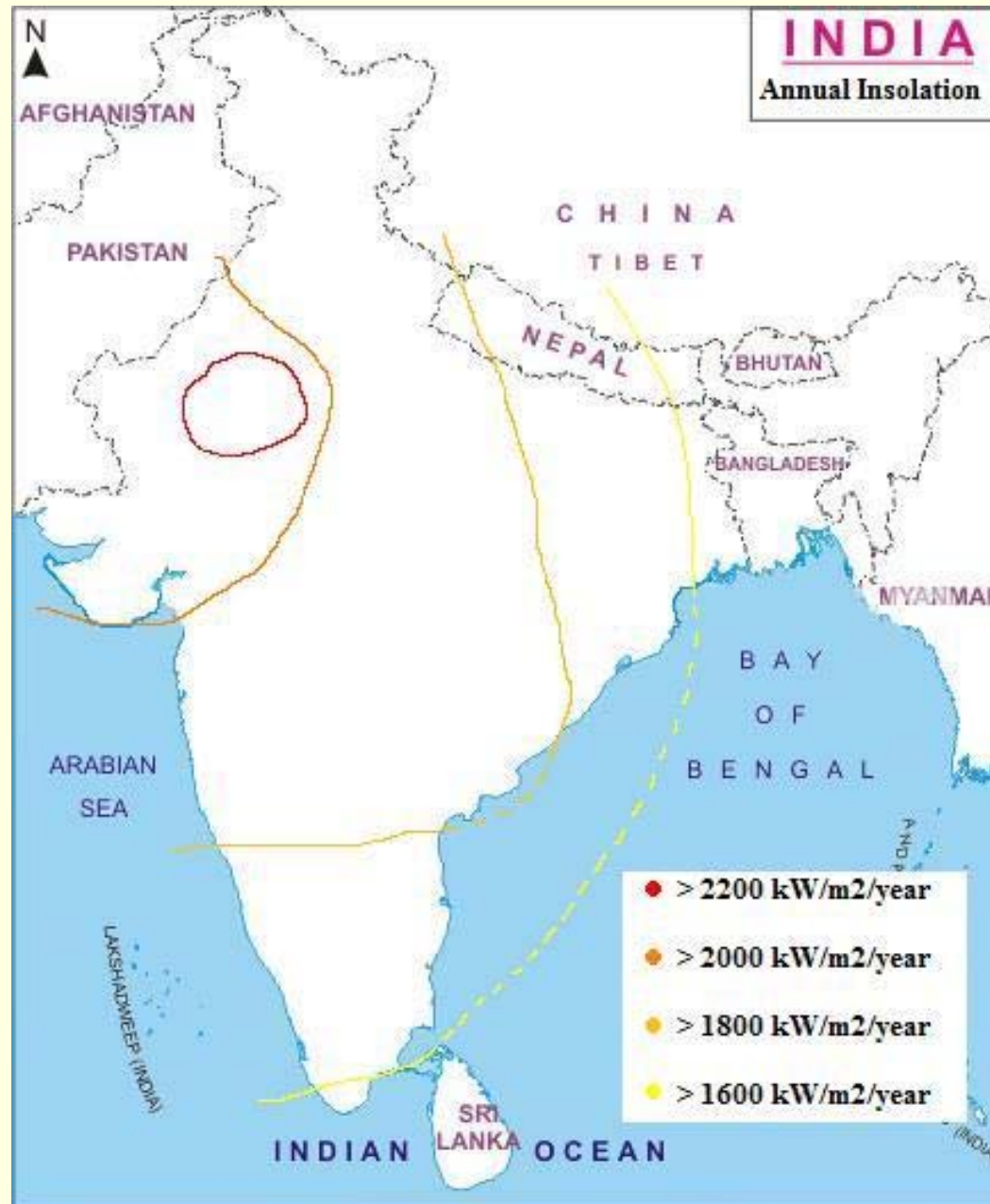
Presentation at DST-EPSRC workshop on April 23rd, 2009 at IIT Delhi



Outline

- What is the potential for solar PV in India?
- What is the status of the solar PV industry in India?
- What is the status of PV research in India?
- What is the status of PV system deployment in India?
- Future for solar PV industry, research and deployment

Annual Insolation



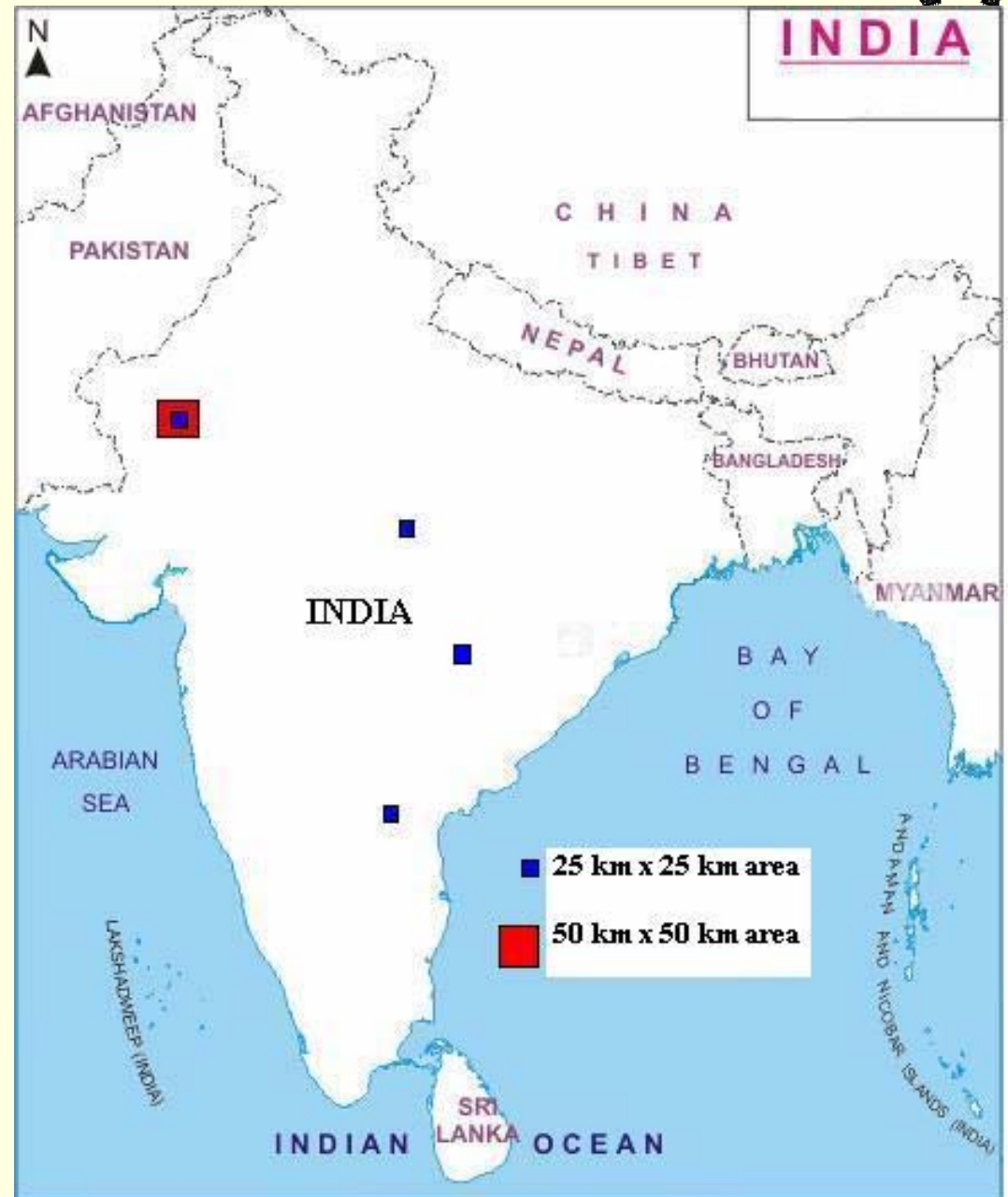
Area for Power Generation



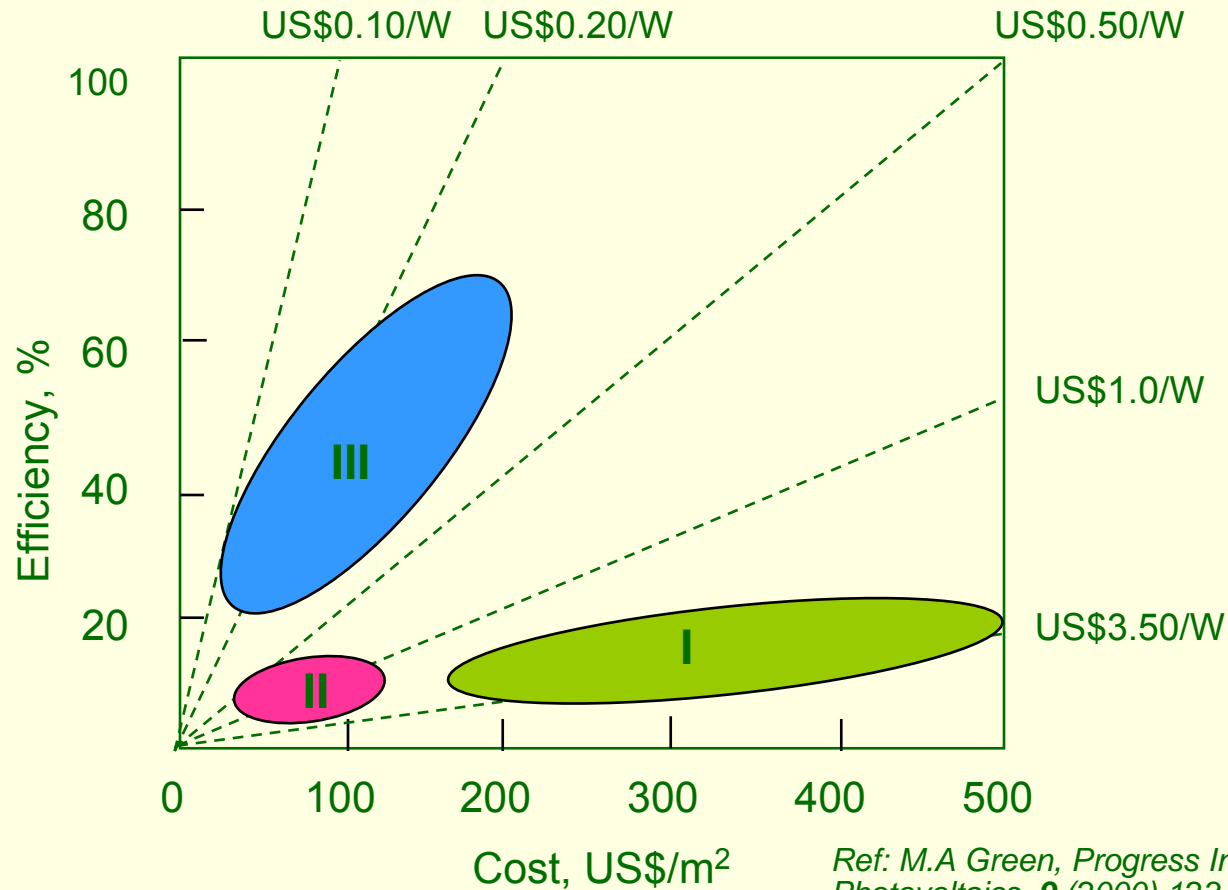
India's present electricity requirement approx. 500 billion kWh, can be met by installing **2500** sq. km of solar field.

A square of 50km x 50km,
or

4 smaller squares of 25km
x 25km.



Photovoltaic Generations: 1st, 2nd & 3rd



1st generation: Si wafer based technologies

2nd generation: Thin-film technologies

3rd generation: Advanced nanostructure based concepts

PV Technologies



1st Gen, Si wafer

Mono-Si

Multi-Si

2nd Gen, Thin-film

a-Si

CdTe

CIGS

μ & Poly-Si

Conc. PV

Multi-Jn GaAs

Organic PV

DSC

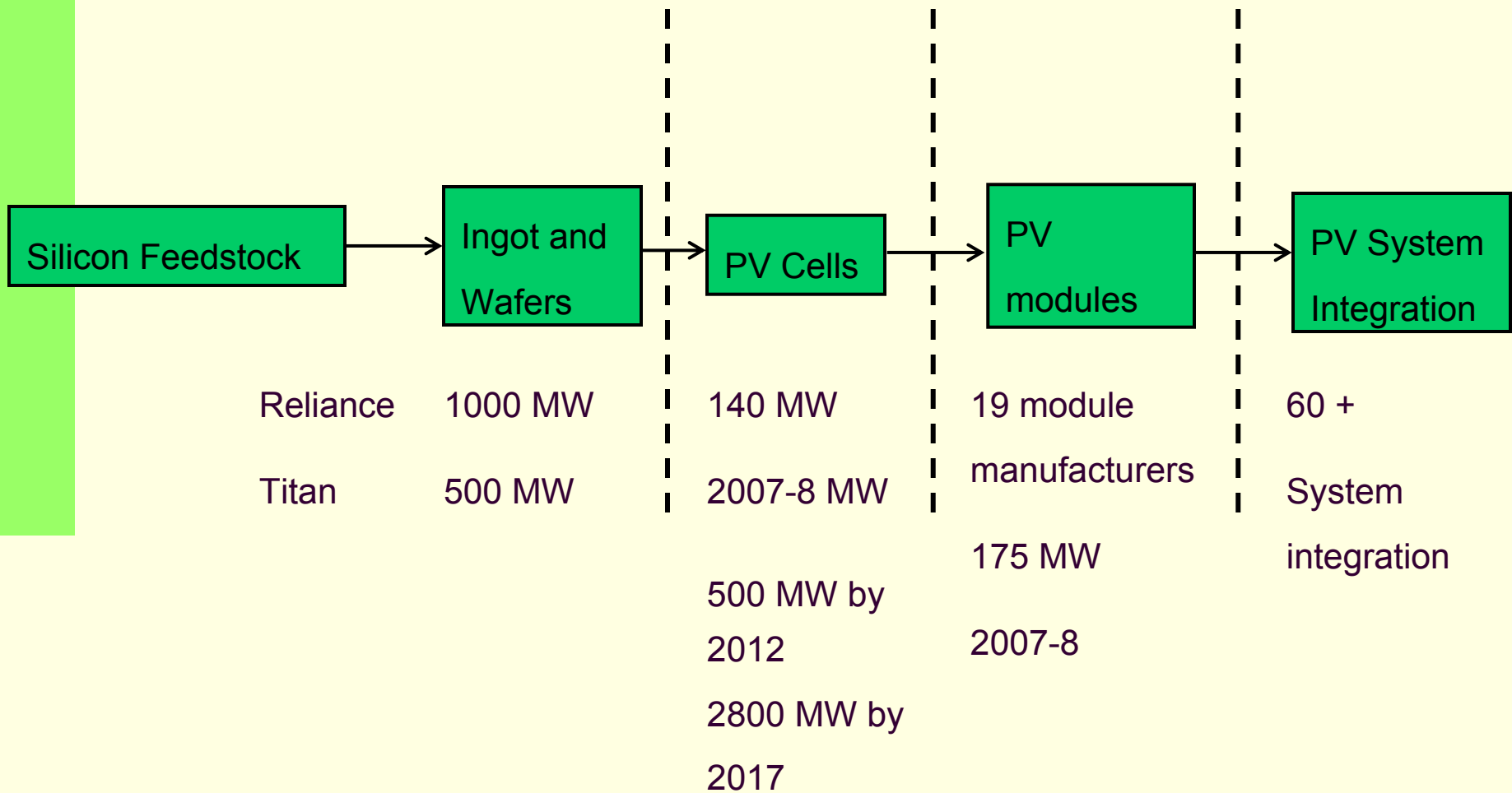
3rd Gen, beyond
single Jn eff. limit

Nano-material
multi-Jn

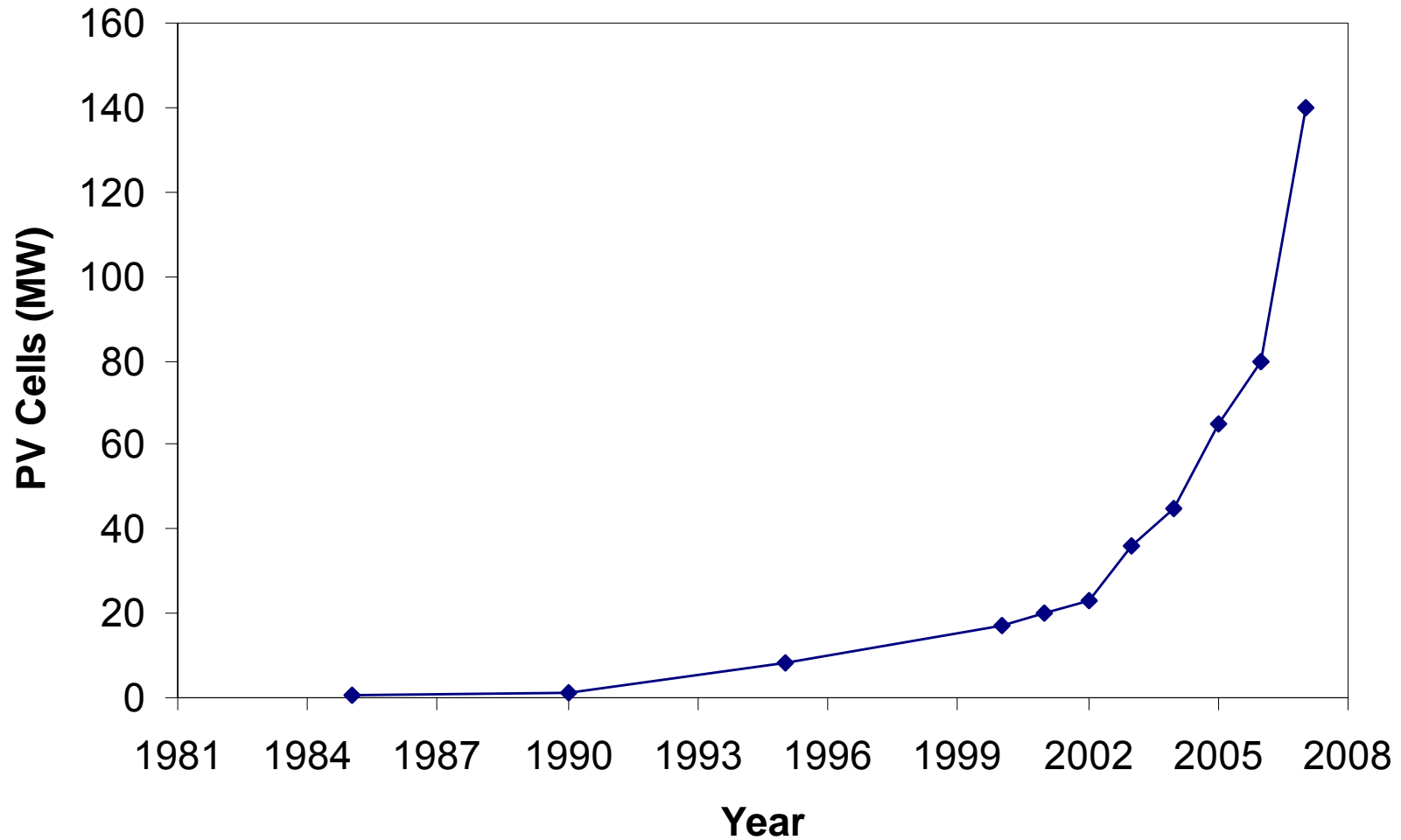
Hot carrier

Spectrum
conversion

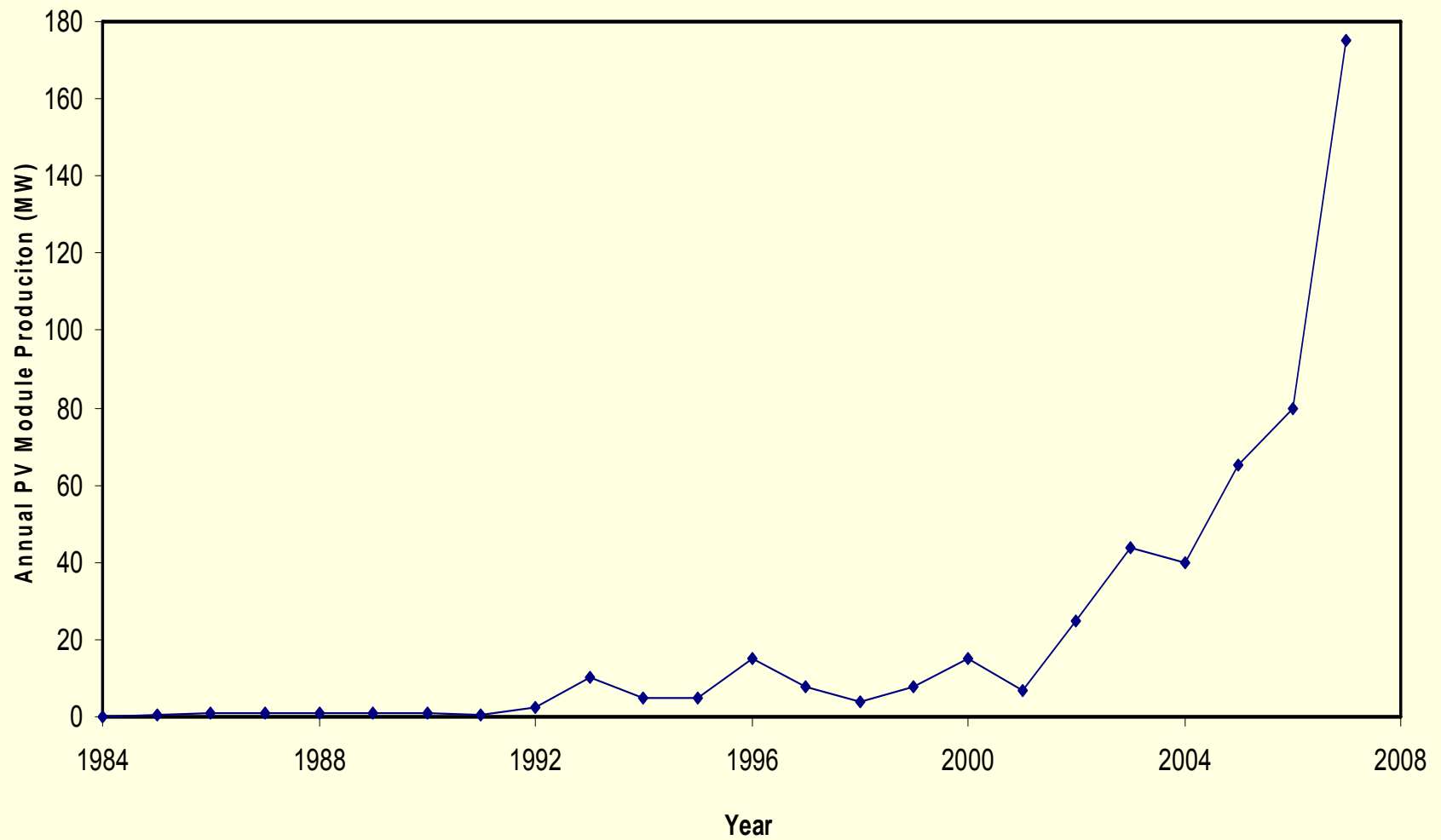
PV system



Annual PV cell Production



Annual PV Module Production



Solar PV Manufacturers in India – Installed Capacities 2008 end



500 MW

700 MW

| Manufacturer | Cells (MW) | Modules (MW) | Expansion Plans |
|----------------------|-------------------|---------------------|------------------------------|
| Tata BP | 180 | 105 | 300 MW by 2010 |
| Solar Semiconductor | 50 | 50 | 60 MW cells, 120 MW modules |
| CEL | 2 | 10 | 10 MW cells by 2010 |
| Reliance | - | 30 | 1000 MW cells in 10 yrs. |
| Moser Baer | 80 | 60 | 580 MW cells, 540 MW modules |
| Maharishi Solar | 2.5 | 3 | 15 MW by 2010 |
| Webel | 10 | 10 | 102 MW by 2010 |
| BHEL | - | 2 | - |
| Titan Energy Sys. | - | 100 | 500 MW by 2010 |
| REIL | 2 | 2 | - |
| Signet Solar | - | - | 340 MW in 2010 |
| Velankani Renewables | - | - | 1500 MW of each |
| Lanco Infratech | - | - | 250 MW modules |
| KSK Energy Ventures | - | - | 700 MW in 10 yrs. |
| Sharp | - | - | 8 MW by 2010 |

Others? IndoSolar Ltd. 360 MW

Publications year wise - India



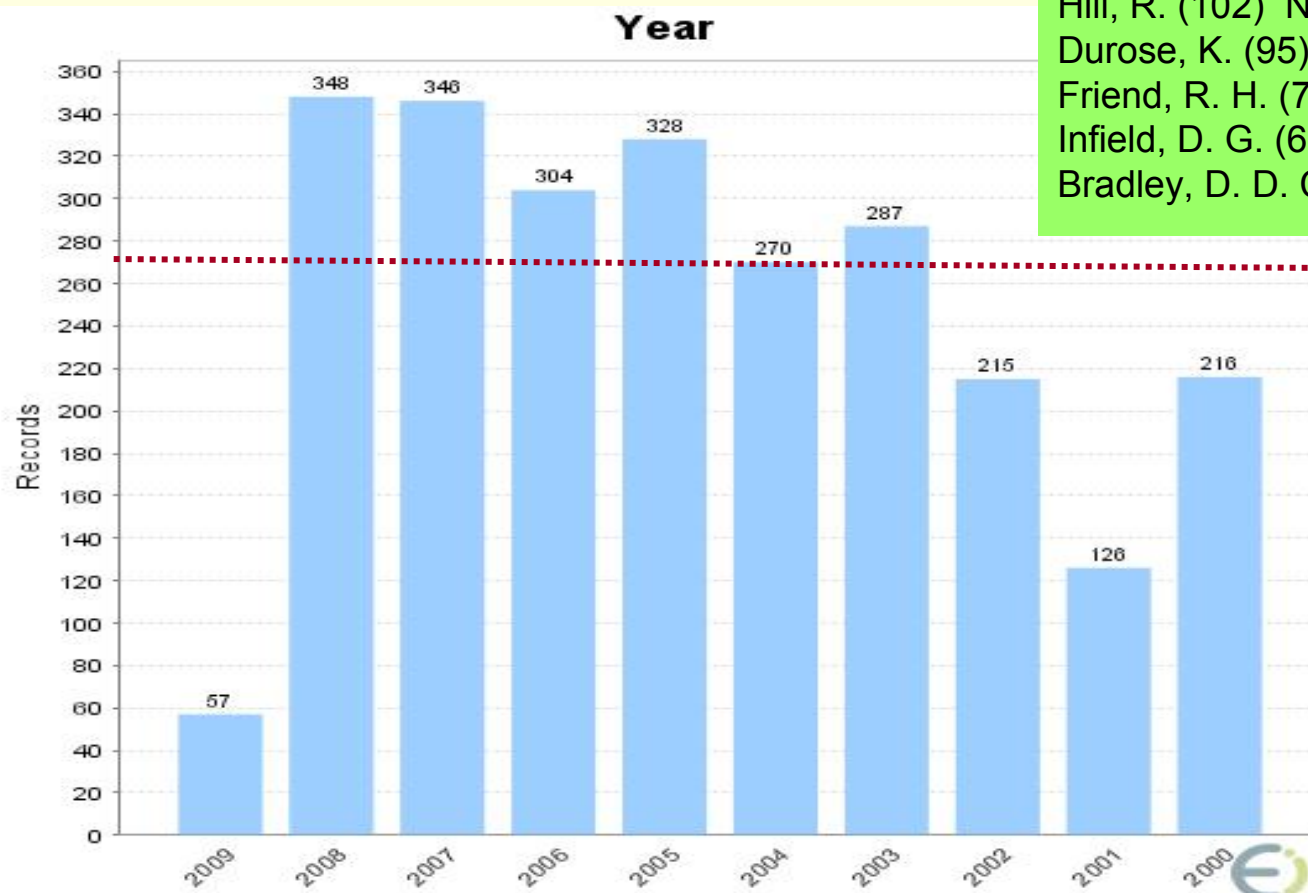
Key words: Solar Cell or PV or Photovoltaics and India (Engineering village)



Publications year wise - United Kingdom



Key words: Solar Cell or PV or Photovoltaics and United Kingdom (Engineering village)



Hill, R. (102) Nelson, J. (101)
Durose, K. (95) Barnham, K. W. J. (92)
Friend, R. H. (72) Peter, L. M. (68)
Infield, D. G. (67) Pearsall, N. M. (66)
Bradley, D. D. C. (62) Roberts, J. S. (61)

Research in first generation PV



1970

Indigenous solar cell – Central Electronics Ltd. (CEL)

1980

National Solar Photovoltaic Energy Development (NASPED) Programme (1980-85)

1 MWp capacity CEL (1985)

1990

IISc Technology for polysilicon material - scaleup by Metkem silicon

BHEL with NSW, Australia and NPL 15-16% efficiency

Independent testing of PV systems – IIT Delhi,
Solar Energy Centre with Sandia Labs

IIT KGP rice husk to polysilicon
material

2000

Research in second generation PV



1970

a-Si IIT Delhi – Indian Association for Cultivation of Science, Univ. of Pune

1980

a-Si Mission Project- IACS, IITD, Univ of Poona, NPL, IITM, IITKGP, IISc
CEL and REIL – Industry partners a-Si η 11-12%

1990

Pilot plant a-Si SEC
BHEL- batch process

IIT Delhi, NPL (CdTe) thin film
IACS. SV univ-CIS

Cochin Univ, Rajasthan Univ – Thin film techniques

2000

CIGS- IISc Bangalore η 13%

Solar PV – policy framework



- **Manufacturing** – Special Incentive Package Scheme – ‘Fab unit’ /‘Ecosystem unit’ Min investment Rs 1000 crores – Capital subsidy of 20% in SEZ and 25% in non SEZ, **SEZ policy** – 100% FDI, several incentives
- **Generation Based Incentives**-MNRE 50 MWp minimum of 1 MWp- guaranteed tariff of Rs 15/kWh (State policies – Gujarat, Rajasthan, Punjab, West Bengal, Haryana)
- **National Climate Change Action Plan** – Solar Mission

Deployment status



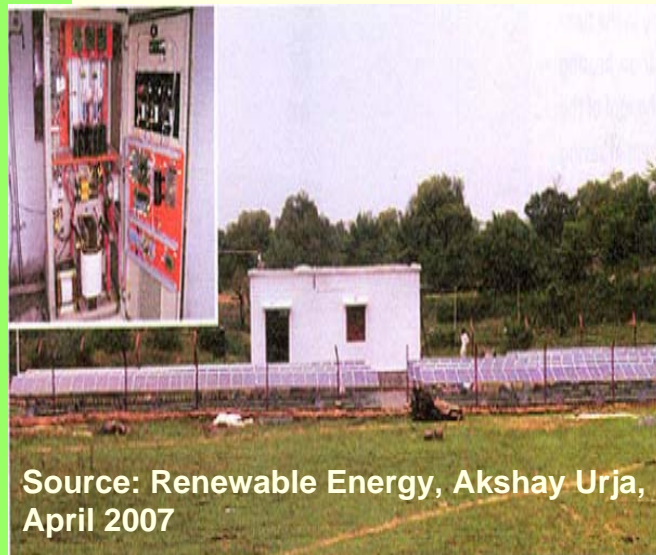
| | |
|-------------------------------------|----------------------|
| Grid interactive solar power | 2.12 MW |
| Off grid solar PV and street lights | 3.00 MWp |
| Home lighting systems | 4,34,692 nos. |
| Solar lanterns | 6,97,419 nos. |
| SPV pumps | 7,148 nos. |

Potential Deployment



- Grid connected PV (~3 MW now), signed 50 MW (250 MW by 2012 – ISA)
- Distributed generation
- Back up power for Telecom (3 kW- 9 kW)
- Roof based building integrated PV
- Solar PV devices
- Solar PV home lighting
- Solar PV for electric vehicles

SPV power plant

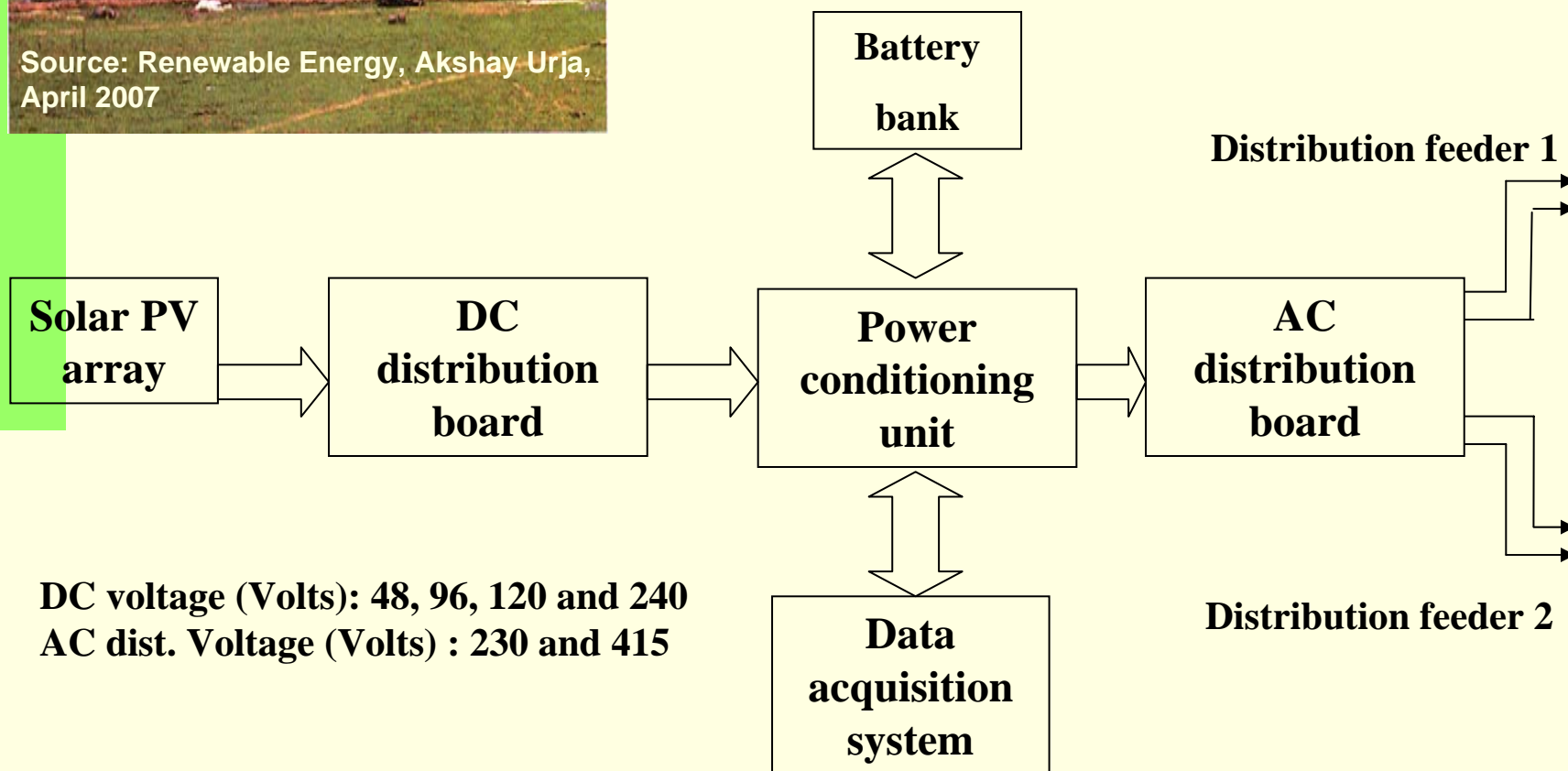


16 kW solar PV power plant at Nurda village, Jharkhand

No. of house holds: 350

Connected load : 10 kW

Source: Renewable Energy, Akshay Urja, April 2007



DC voltage (Volts): 48, 96, 120 and 240
AC dist. Voltage (Volts) : 230 and 415

Isolated SPV power plants in India



Installed capacity (As on 31/01/2009) : 2.8 MWp

Total number of SPV power plants : 230 Nos.

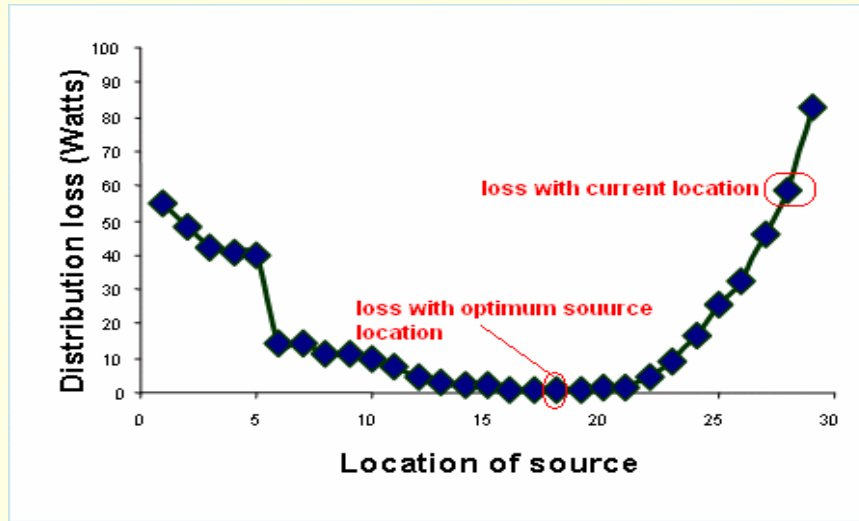
| S.No. | State | PV Capacity (kWp) | No. of power plants |
|-------|--------------|-----------------------|------------------------|
| 1 | Maharashtra | 5 | 2 |
| 2 | Chattisgargh | 1 to 6 | 108 |
| 3 | Rajasthan | 17.25 34.5 | 82 1 |
| 4 | Jharkhand | 28 | 1 |
| 5 | Orissa | 2 | 11 |
| 6 | Haryana | 10 | - |
| 7 | Mizoram | 25 | 1 |
| 8 | UP (NTPC) | 11.9 kW | 1 |
| 9 | West Bengal | 25 kW | 15 |

Isolated SPV power plants in India

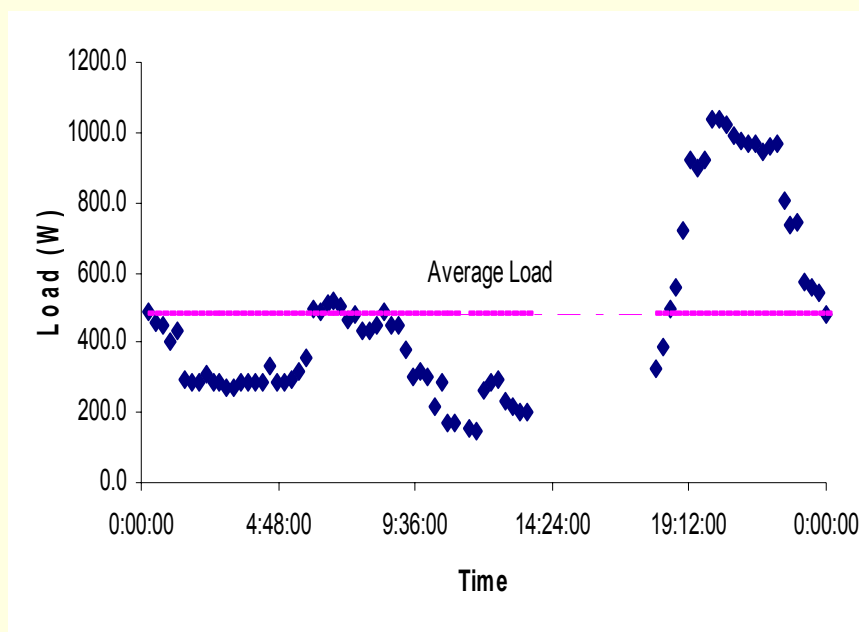


| Plant | (kWp) | Invert er (kVA) | Charge controll er (kW) | Battery capacity (Ah) | Battery Voltag e (Volts) | Distributi on Voltage (Volts) | Connect ed Load (kW) | Plant Capacity factor (%) |
|--------------------------------------|--------|-----------------------|-------------------------------|-----------------------------|-----------------------------------|--|-------------------------------|---------------------------------|
| Dound II, Chattisgargh | 1 | 1.5 | - | - | 48 | 230 | 0.3 | 5.8 |
| Latdadar, Chattisgargh | 2 | 3 | - | - | 48 | 230 | 0.7 | 7.1 |
| Chatal, Chattisgargh | 3 | 5 | - | - | 48 | 230 | 0.7 | 4.4 |
| Gudagarh, Chattisgargh | 4 | 5 | 5 | 800 | 48 | 230 | 1.2 | 6.3 |
| Rajmachi, Maharashtra | 5 | 7.5 | 5 | 800 | 120 | 230 | 1.4 | 8.2 |
| Sura, Udaipur, Rajasthan | 17.25 | 15 | 20 | 1200 | 120 | 230 | 5.0 | 7.3 |
| Nurda village, Jharkhand | 28 | 20 | 25 | 1200 | 120 | 230 | 9.5 | 8.5 |
| Anandgarh, Bikaner, Rajasthan. | 34.5 | 2*15 | 2*20 | 2*1200 | 120 | 230 | 10 | 7.5 |

System Design issues



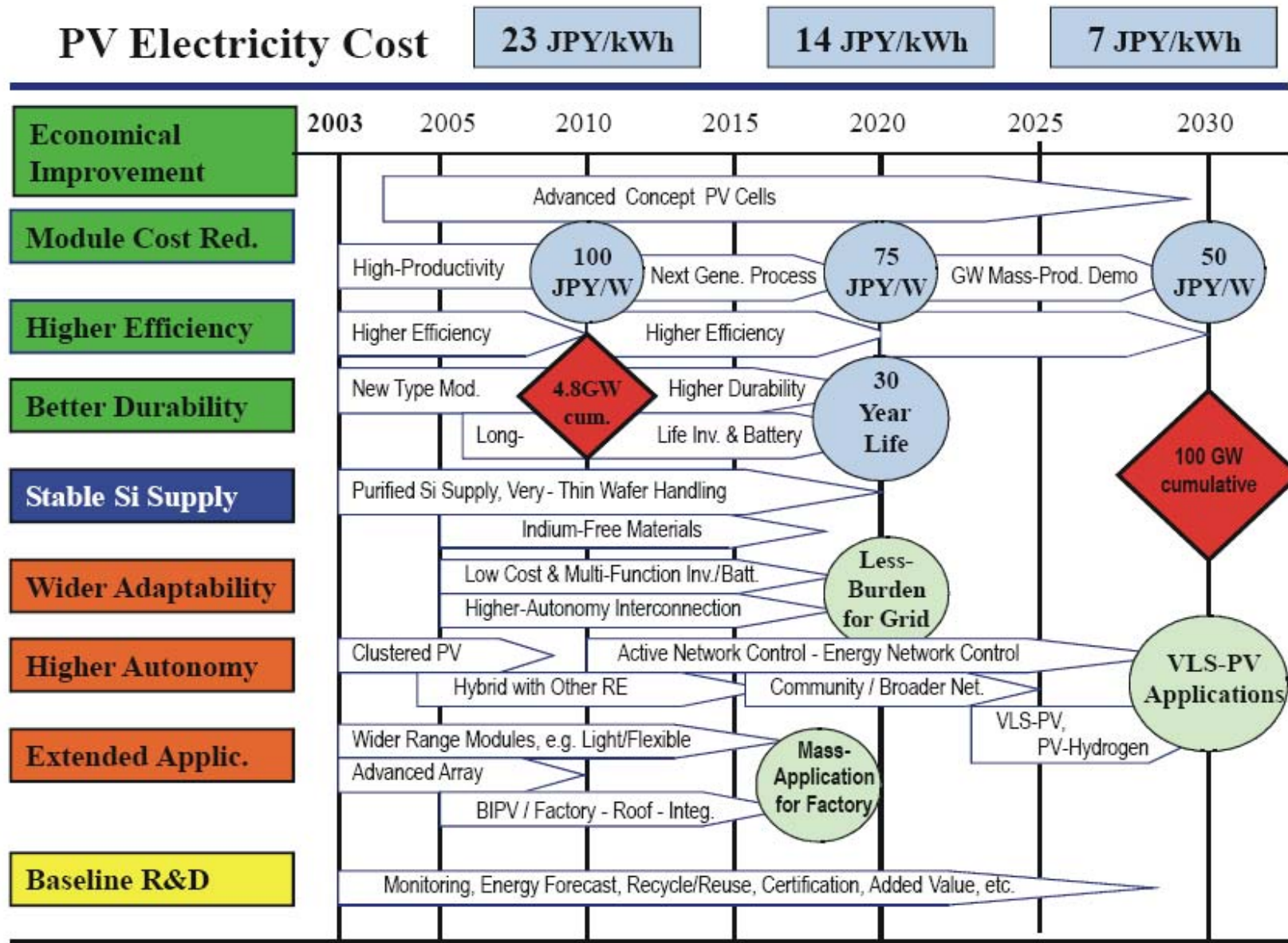
Low conc V trough (C Solanki)



5 kWp Village power, Maharashtra

**Oversized systems,
Non optimal distribution,
Hybrid**

PV Roadmap in Japan

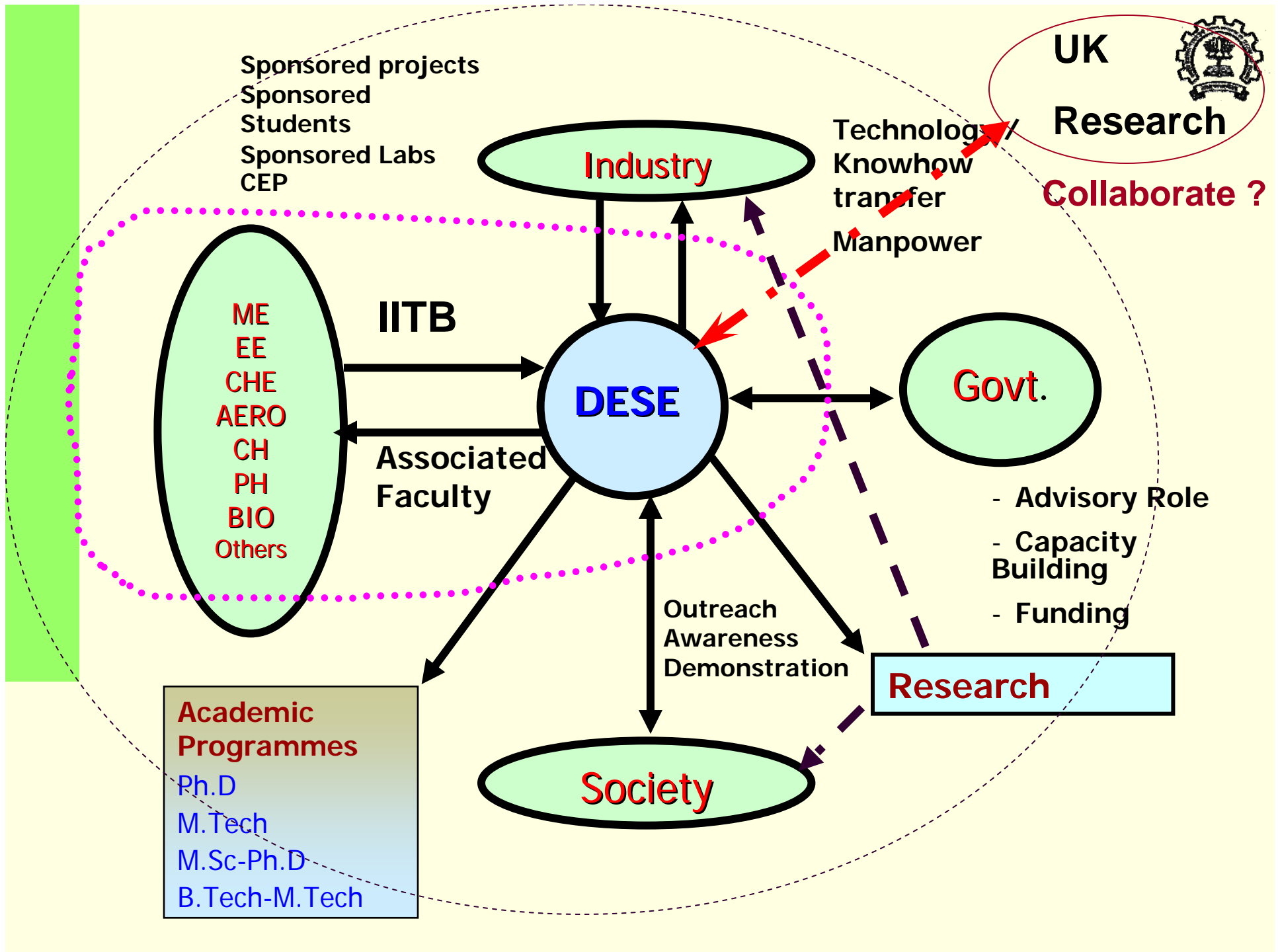


Source: PV status report (2008)

India – Future needs



- Road Map – 1st generation –process improvement, cost reduction-industry link, 2nd generation –repeatability, efficiency, life, 3rd generation – fundamental work + scale-up.
- Cost effective power electronics, micro inverters, MPPT, batteries
- Independent Performance assessment
- Innovative solutions – devices, business models, ideas – ‘Renewable Energy Search’ , Business Incubation
- Missing lab to plant link
- Create critical mass of researchers – PhD,post-docs, industry links
- Consortium models – reconcile competition v/s collaboration, open domain v/s commercial



India and UK (2005 Statistics)



| | | |
|---|--------------------------|------------------------|
| Population | 1095 million | 60 million |
| GDP (PPP) | 3362 Billion US\$ | 1627 Billion US\$ |
| Primary Energy | 22.4 EJ | 9.8 EJ |
| Energy/person | 20.5 GJ/person/year | 163.3 GJ/person/year |
| Electricity/person | 480 kWh/capita/year | 6254kWh/capita/year |
| CO2 emissions Per person Per GDP | 1147 Million tonnes | 530 Million tonnes |
| | 1.05 tonnes /capita/year | 8.8tonnes /capita/year |
| | 0.31 kg /US\$ | 0.34 kg /US\$ |

Source: IEA

Synergies- Possible collaboration



- Identification of 'win-win' options
- Deployment potential better in India
- Leveraging availability of cutting edge facilities, characterisation and manufacturing
- Creating research fabs
- Manpower training , capacity building
- Mechanism for two way exchange of PhD students, researchers, faculty
- White paper – wish list – collaboration goals

References



- B. Bhargava, Photovoltaic Technology Development in India: an overview, 25 years of Renewable energy in India, MNRE, New Delhi, 2008.
- Solar PV Industry: Global and Indian Scenario, ISA-NMCC, September 2008.
- M.A Green, Progress In Photovoltaics, **9** (2000) 123.
- A.K.Barua, A, Sarker, Solar Photovoltaic Electricity, Status, Prospects and Challenges, TIFAC, New Delhi, 2007
- A.J.Waldgau, PV status report 2008, EC report, Sept 2008
- The solar PV landscape in India, SEMI white paper, April 2009

Acknowledgements:

Chetan Solanki, Balkrishna Surve, Mel George, Manoj Kumar, Pranesh Krishnamurthy, Ranjeet Bhalerao, J. Vasi

Thank you