



# Solar Photovoltaics in India

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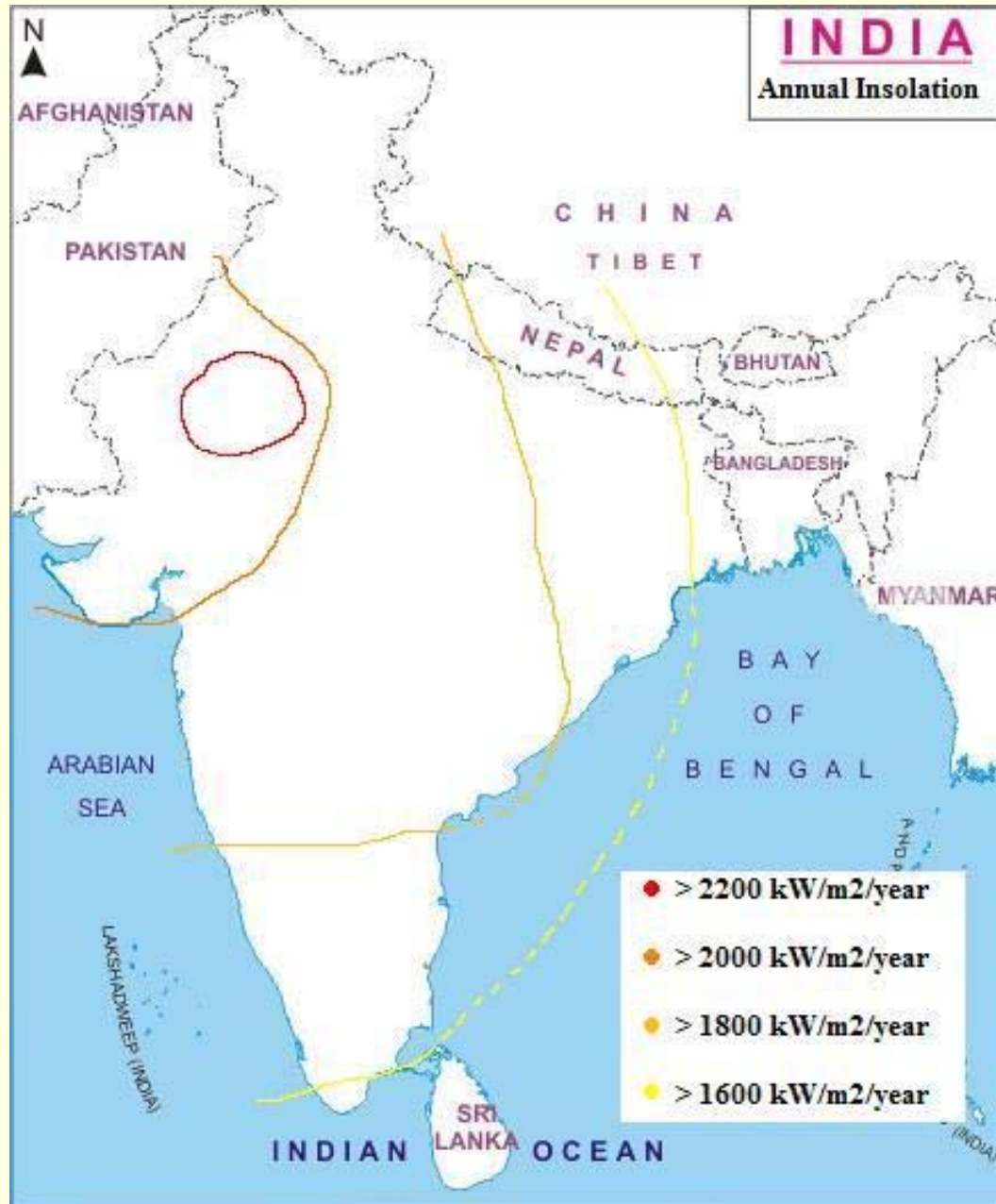




# Outline

- 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



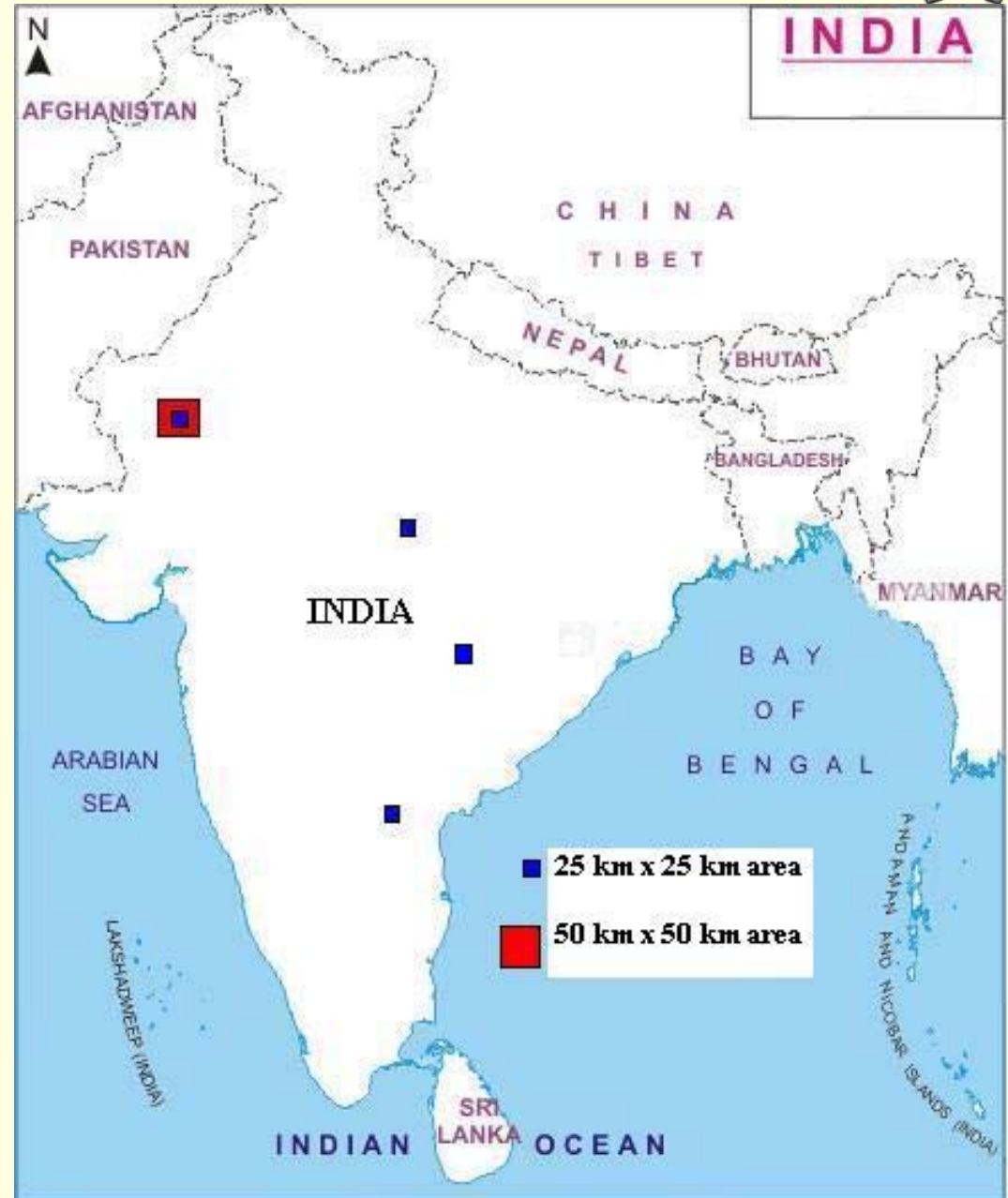
# Area for Power Generation



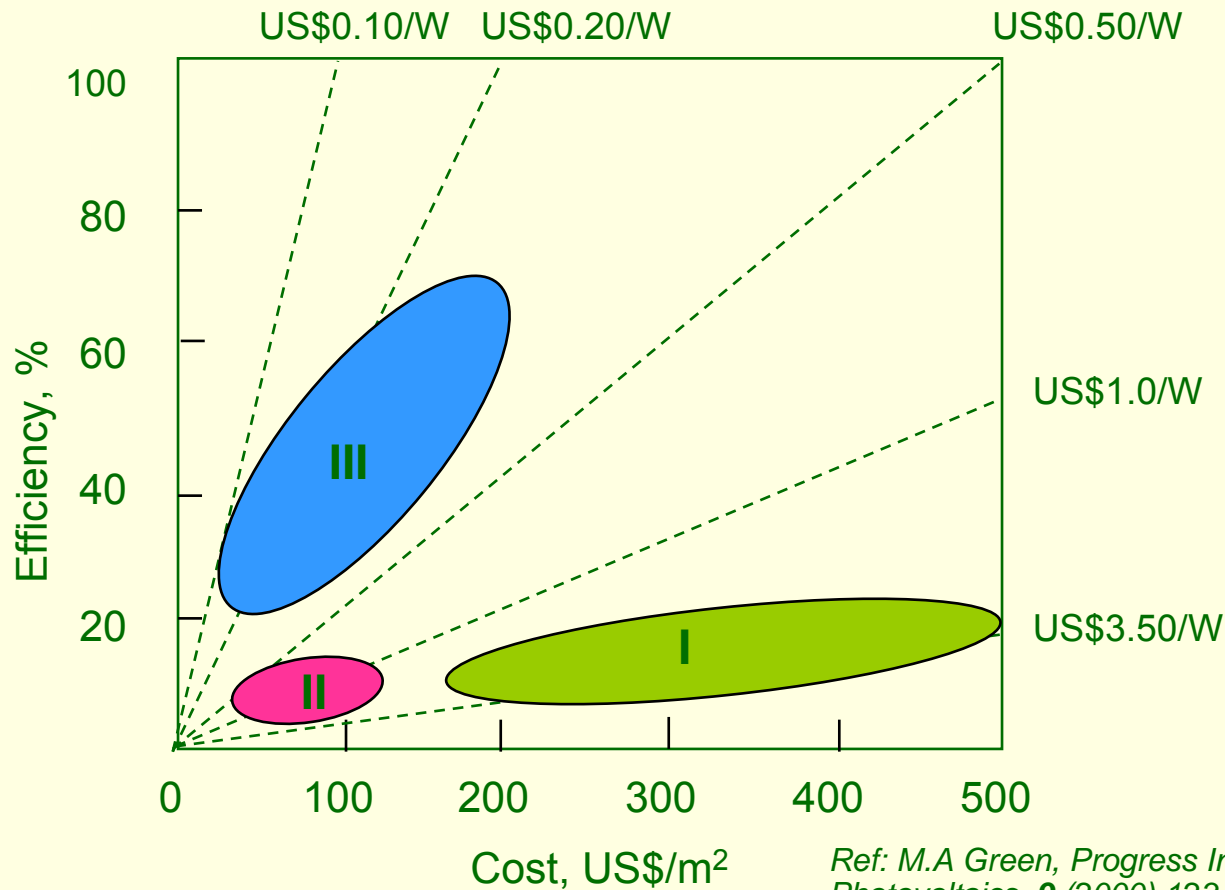
India's present electricity requirement approx. 500 billion kWh, can be met by installing **2500** sq. km of solar field.

A square of 50km x 50km,  
or

4 smaller squares of 25km  
x 25km.



# Photovoltaic Generations: 1<sup>st</sup>, 2<sup>nd</sup> & 3<sup>rd</sup>



**1<sup>st</sup> generation:** Si wafer based technologies

**2<sup>nd</sup> generation:** Thin-film technologies

**3<sup>rd</sup> generation:** Advanced nanostructure based concepts

# PV Technologies



1<sup>st</sup> Gen, Si wafer

Mono-Si

Multi-Si

2<sup>nd</sup> Gen, Thin-film

a-Si

CdTe

CIGS

$\mu$  & Poly-Si

Conc. PV

Multi-Jn GaAs

Organic PV

DSC

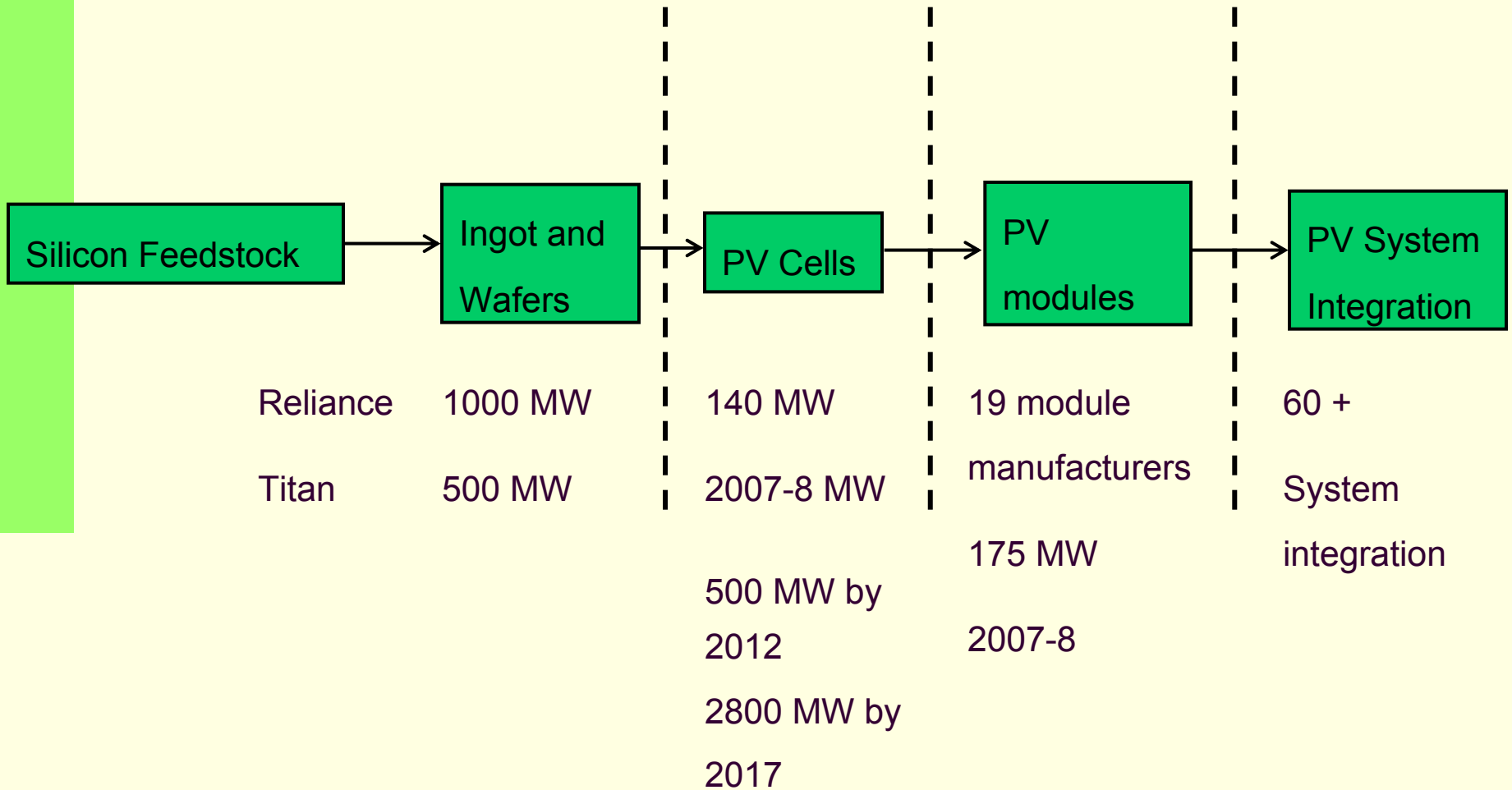
3<sup>rd</sup> Gen, beyond  
single Jn eff. limit

Nano-material  
multi-Jn

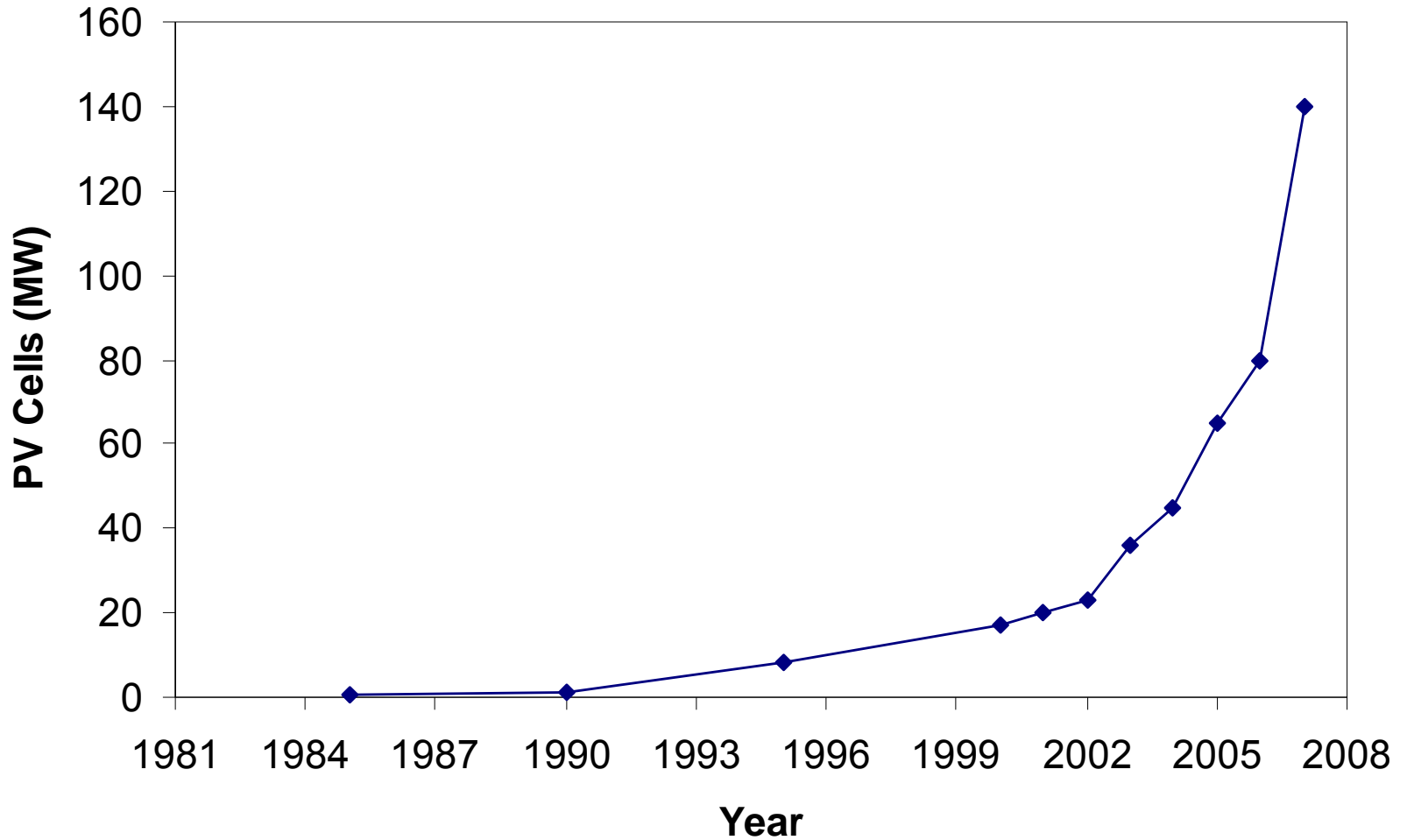
Hot carrier

Spectrum  
conversion

# PV system

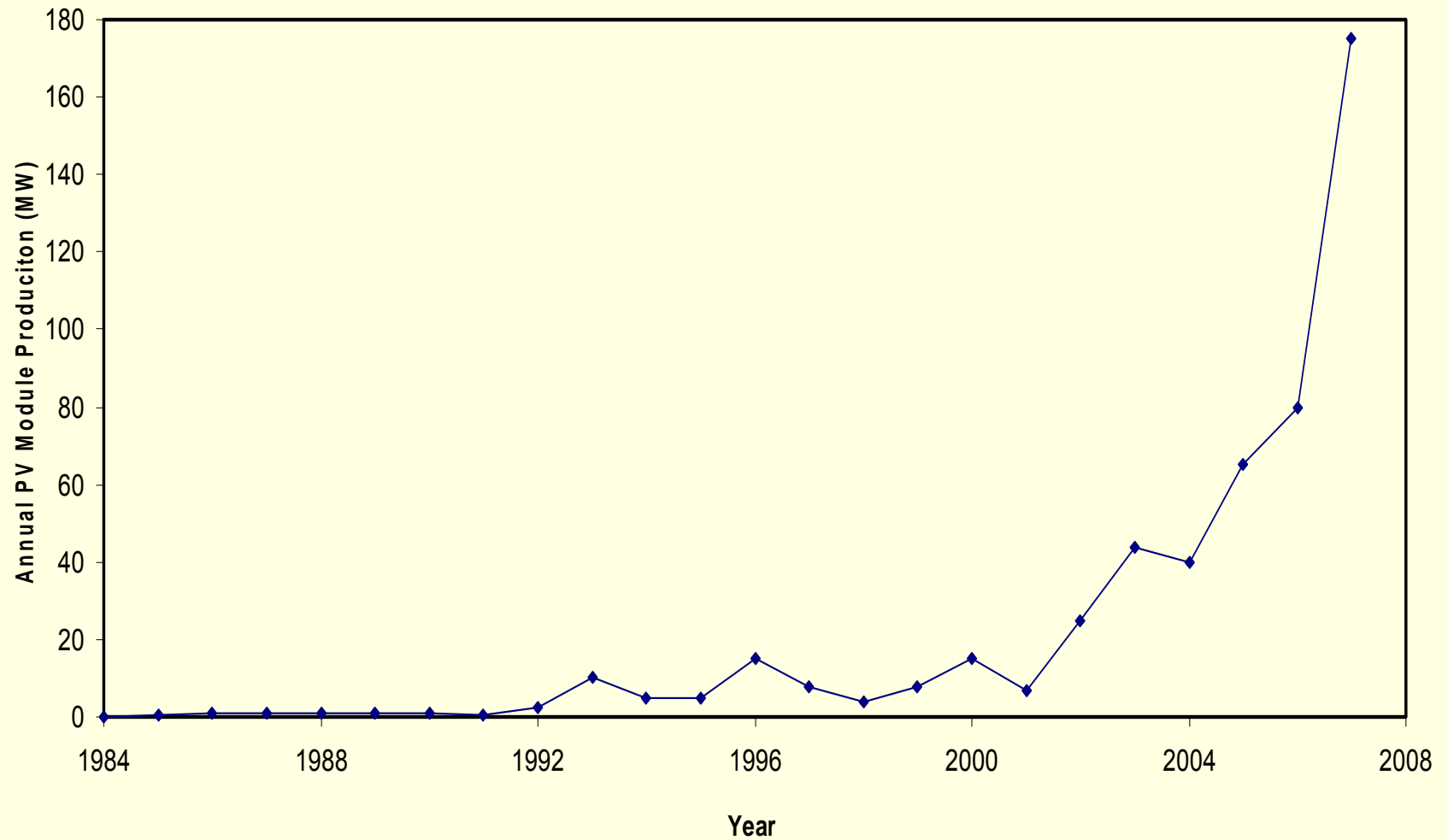


# Annual PV cell Production





# Annual PV Module Production



# Solar PV Manufacturers in India – Installed Capacities 2008 end



**500 MW**

**700 MW**

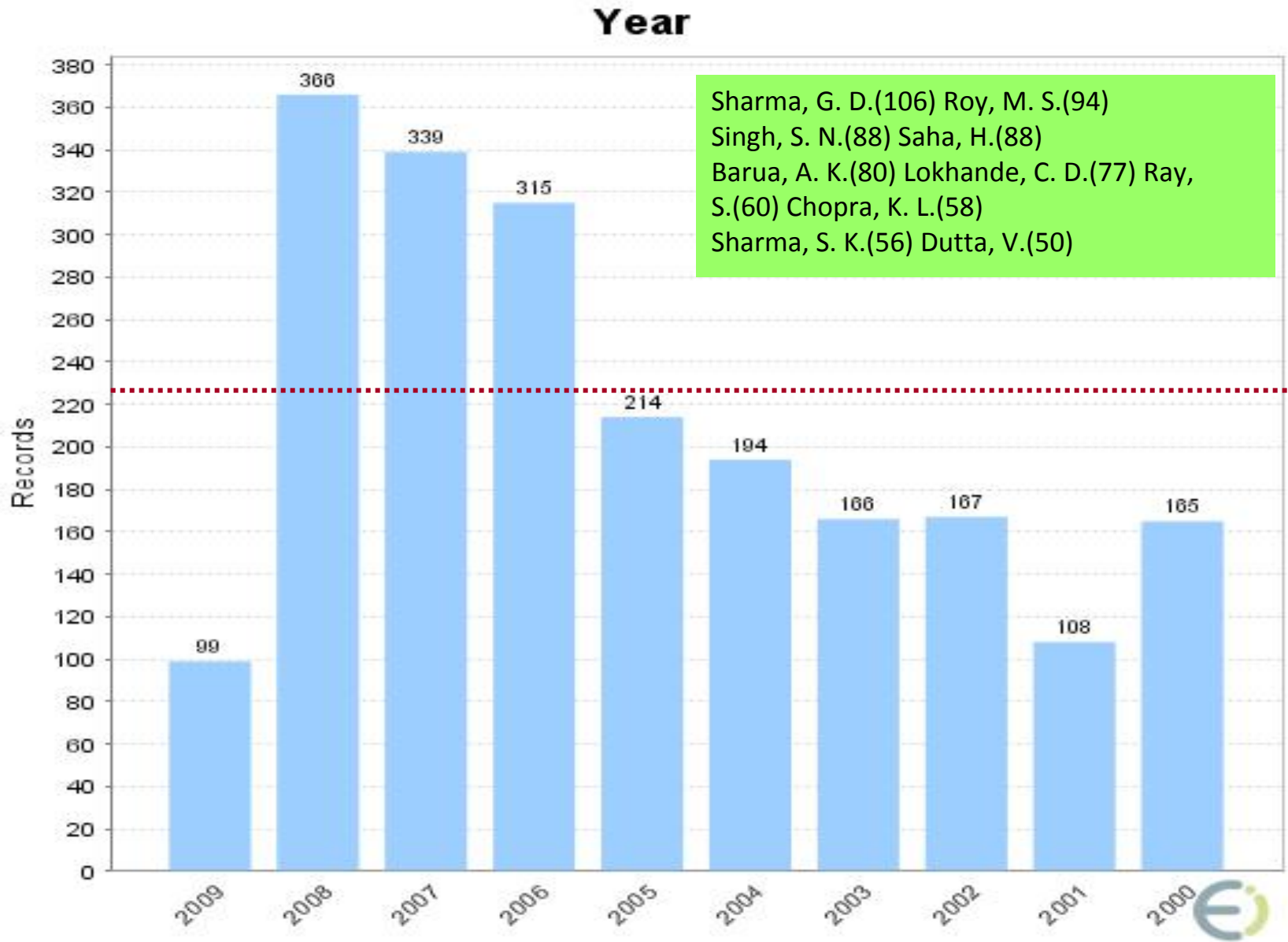
<b>Manufacturer</b>	<b>Cells (MW)</b>	<b>Modules (MW)</b>	<b>Expansion Plans</b>
Tata BP	180	105	300 MW by 2010
Solar Semiconductor	50	50	60 MW cells, 120 MW modules
CEL	2	10	10 MW cells by 2010
Reliance	-	30	1000 MW cells in 10 yrs.
Moser Baer	80	60	580 MW cells, 540 MW modules
Maharishi Solar	2.5	3	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



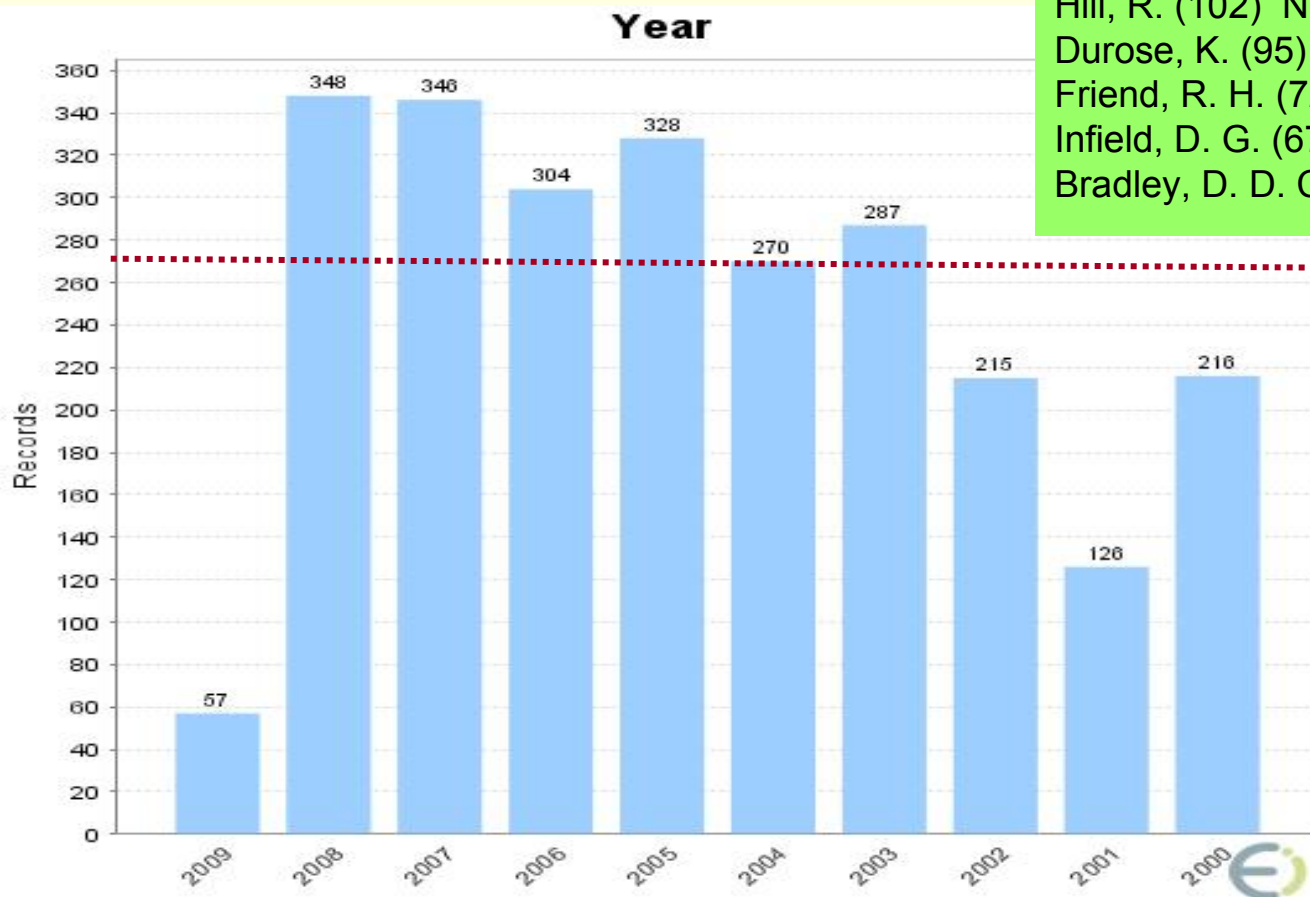
Key words: Solar Cell or PV or Photovoltaics and India (Engineering village)



# Publications year wise - United Kingdom

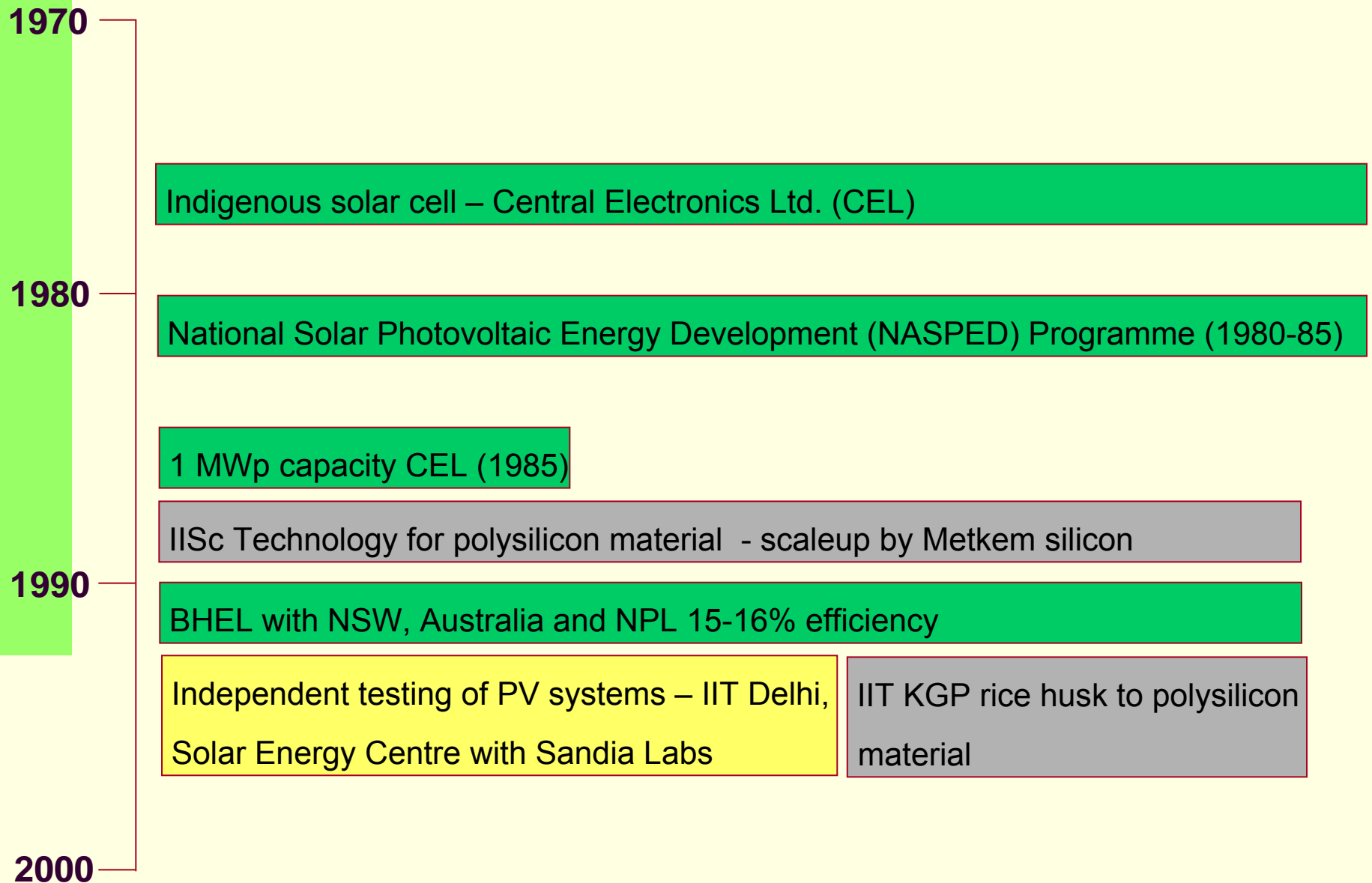


Key words: Solar Cell or PV or Photovoltaics and United Kingdom (Engineering village)

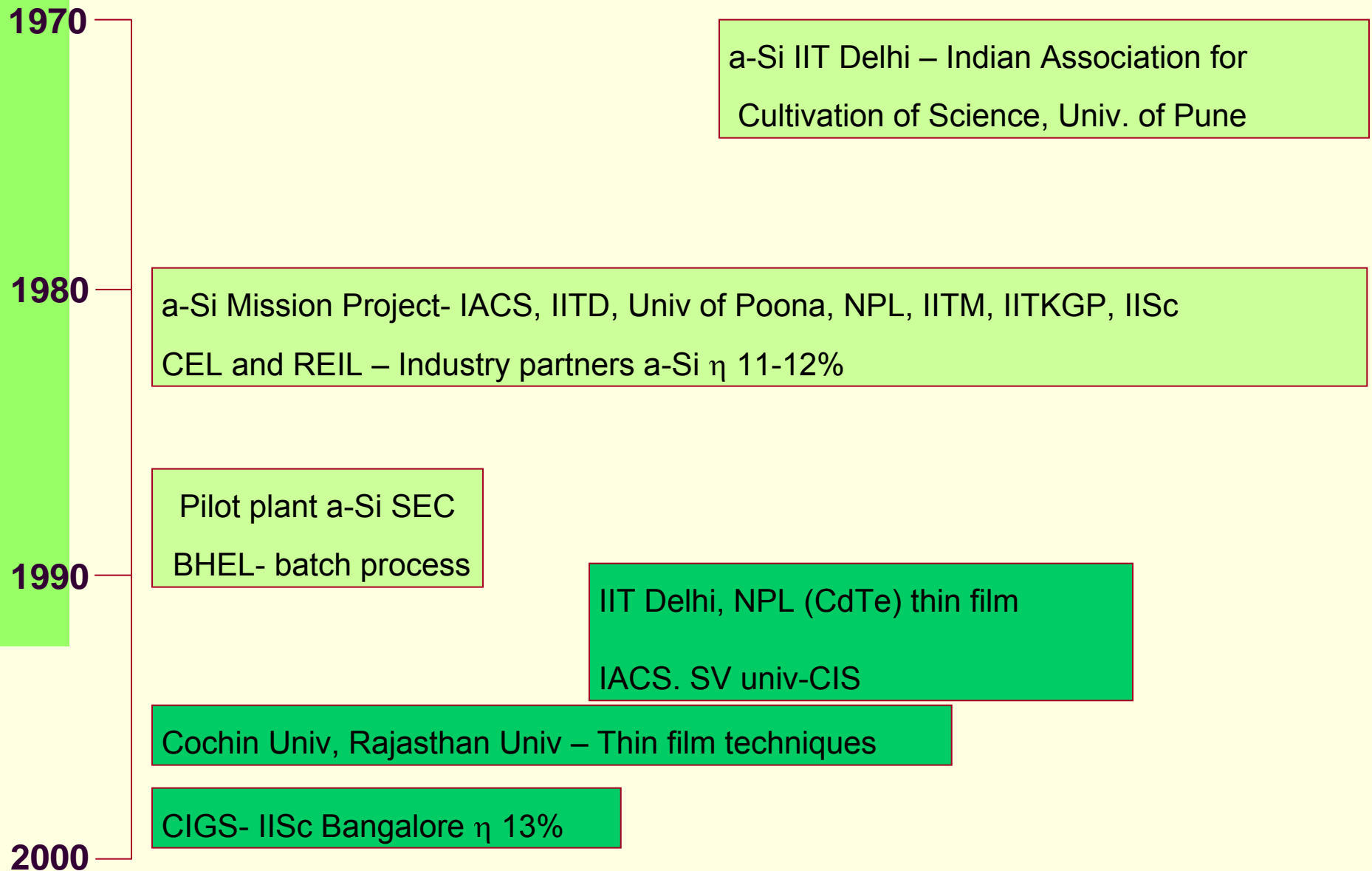


Hill, R. (102) Nelson, J. (101)  
Durose, K. (95) Barnham, K. W. J. (92)  
Friend, R. H. (72) Peter, L. M. (68)  
Infield, D. G. (67) Pearsall, N. M. (66)  
Bradley, D. D. C. (62) Roberts, J. S. (61)

# Research in first generation PV



# Research in second generation PV





# 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	<b>2.12 MW</b>
Off grid solar PV and street lights	<b>3.00 MWp</b>
Home lighting systems	<b>4,34,692 nos.</b>
Solar lanterns	<b>6,97,419 nos.</b>
SPV pumps	<b>7,148 nos.</b>

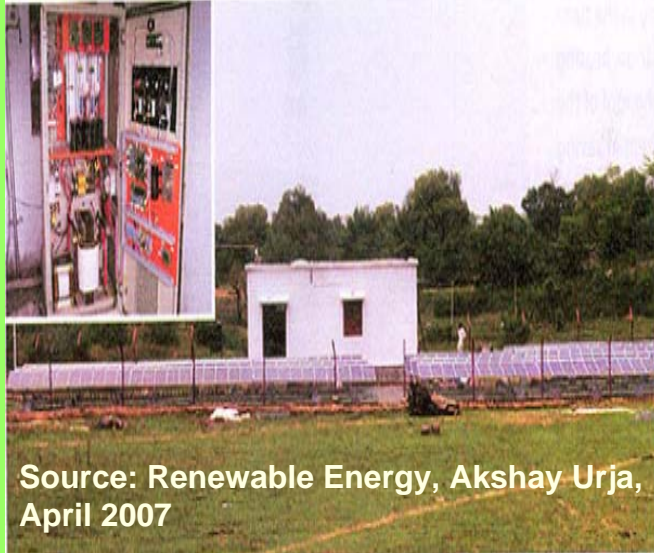


# Potential Deployment



- 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

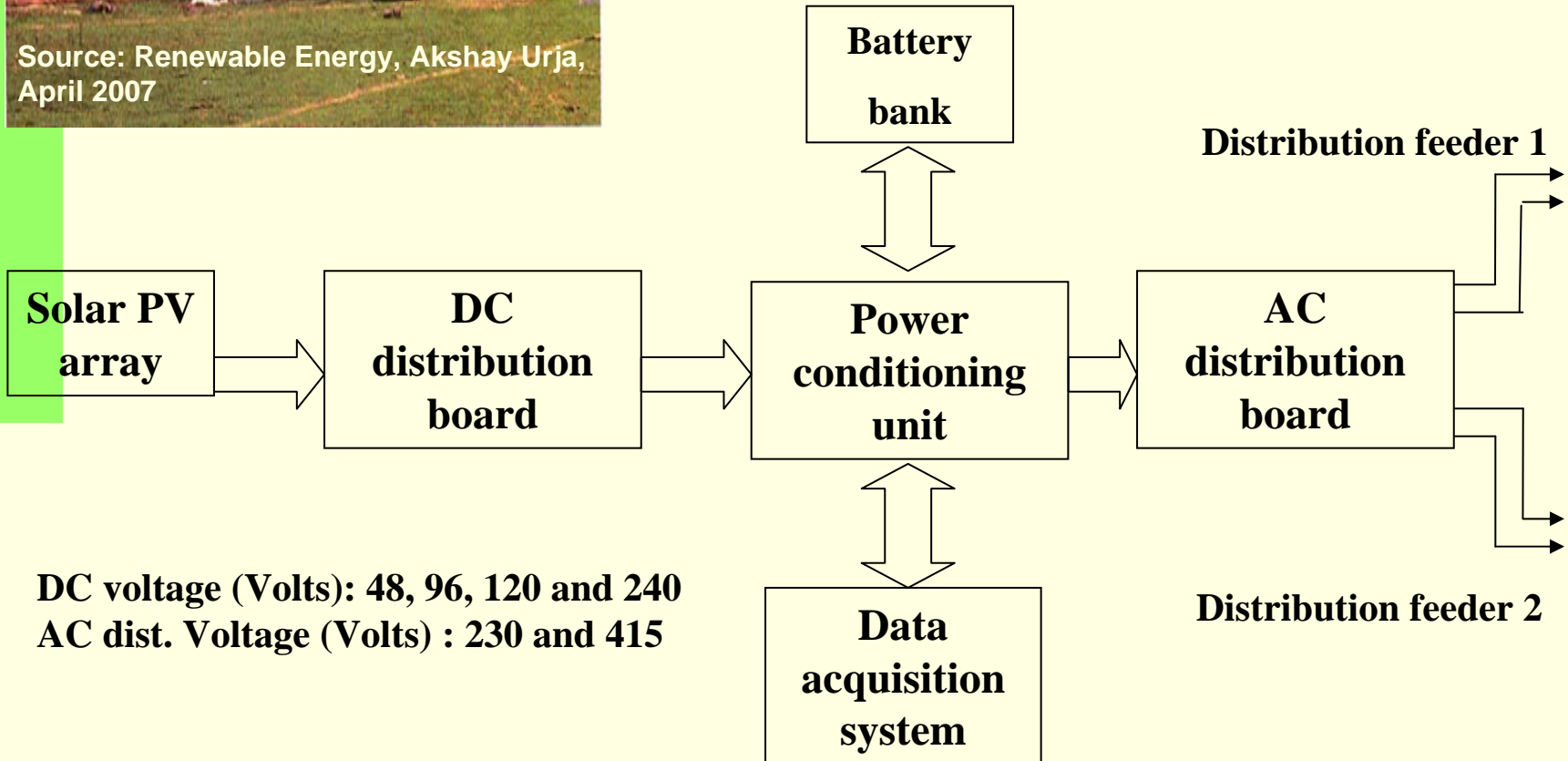
# SPV power plant



**16 kW solar PV power plant at  
Nurda village, Jharkhand**

**No. of house holds: 350**

**Connected load : 10 kW**



# Isolated SPV power plants in India



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

**Total number of SPV power plants : 230 Nos.**

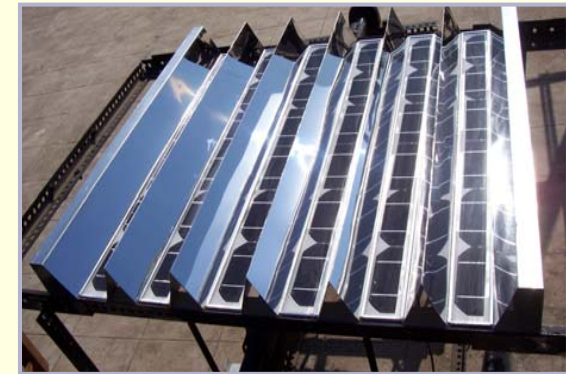
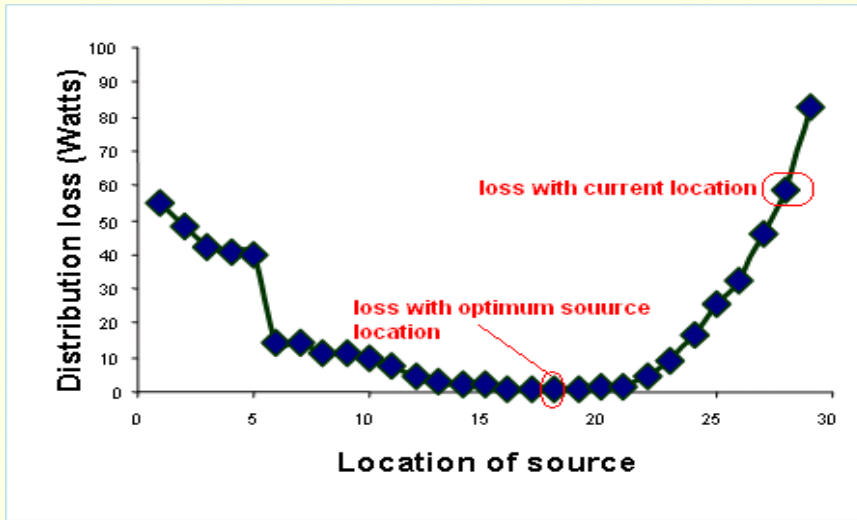
S.No.	State	PV Capacity ( kWp)	No. of power plants
1	Maharashtra	5	2
2	Chattisgargh	1 to 6	108
3	Rajasthan	17.25 34.5	82 1
4	Jharkhand	28	1
5	Orissa	2	11
6	Haryana	10	-
7	Mizoram	25	1
8	UP (NTPC)	11.9 kW	1
9	West Bengal	25 kW	15

# Isolated SPV power plants in India

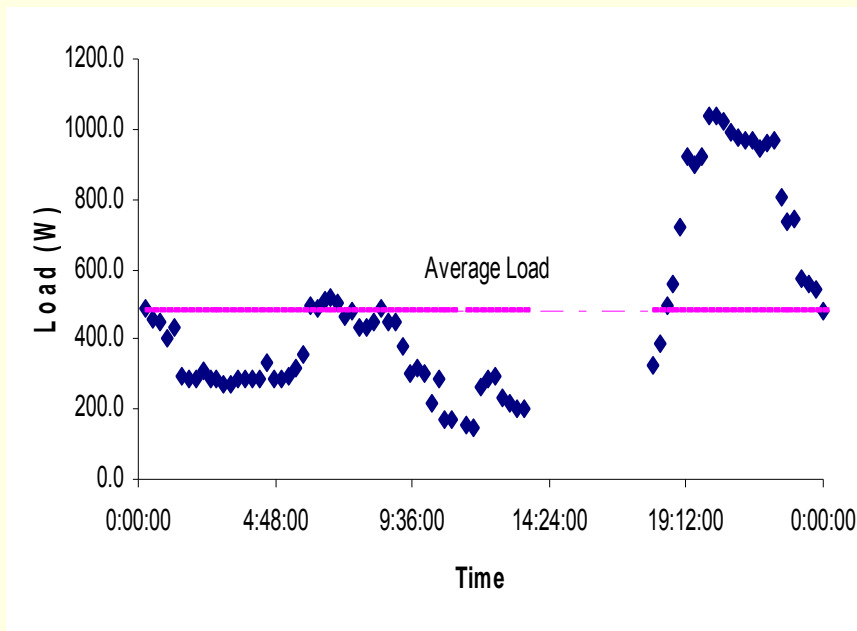


Plant	( kWp)	Invert er (kVA)	Charge controll er (kW)	Battery capacity (Ah)	Battery Volutag e (Volts)	Distributi on Voltage (Volts)	Connect ed Load (kW)	Plant Capacity factor (%)
Dound II, Chattisgargh	1	1.5	-	-	48	230	0.3	5.8
Latdadar, Chattisgargh	2	3	-	-	48	230	0.7	7.1
Chatal, Chattisgargh	3	5	-	-	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



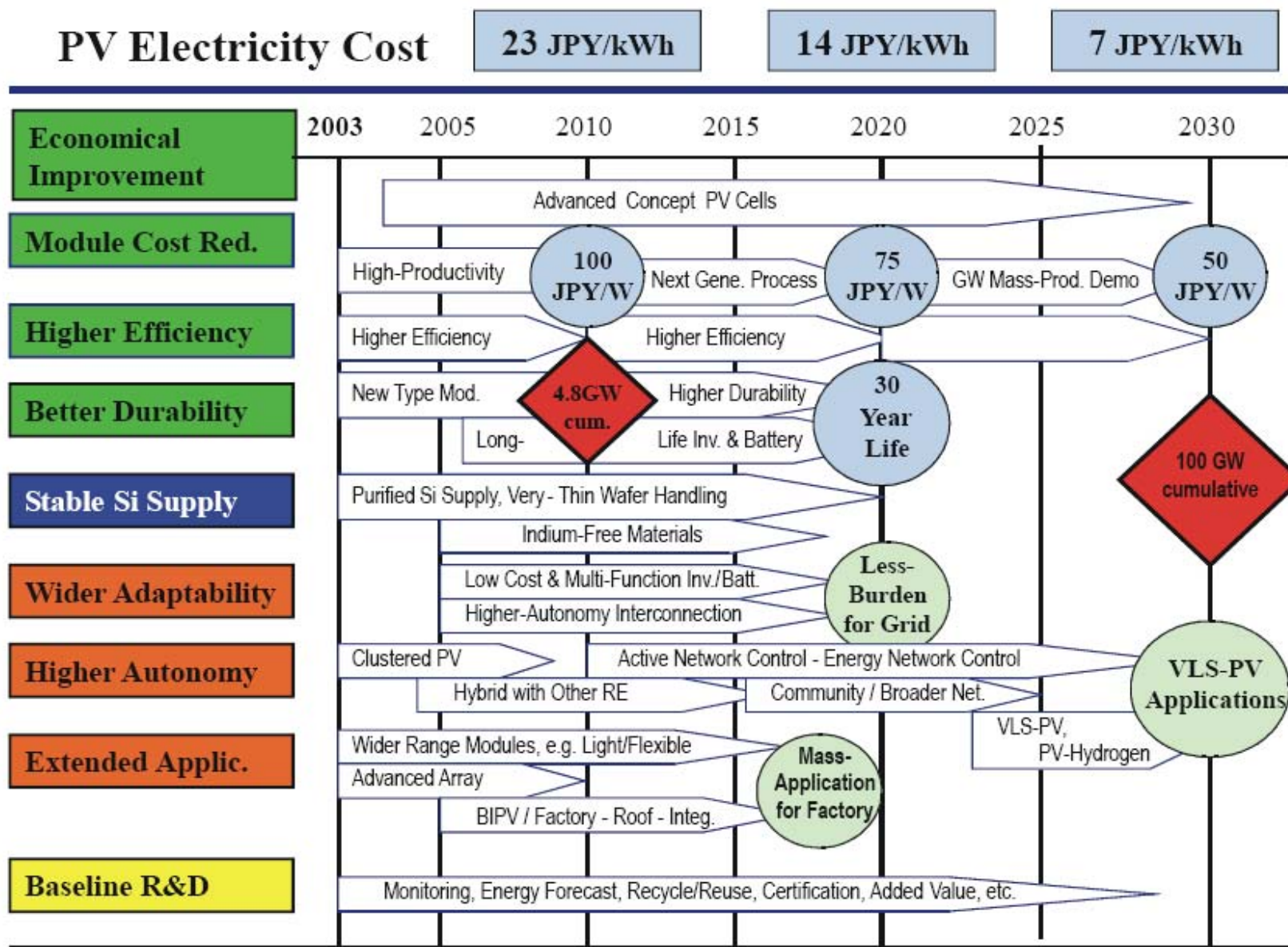
Low conc V trough (C Solanki)



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 – 1<sup>st</sup> generation –process improvement, cost reduction-industry link, 2<sup>nd</sup> generation –repeatability, efficiency, life, 3<sup>rd</sup> 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

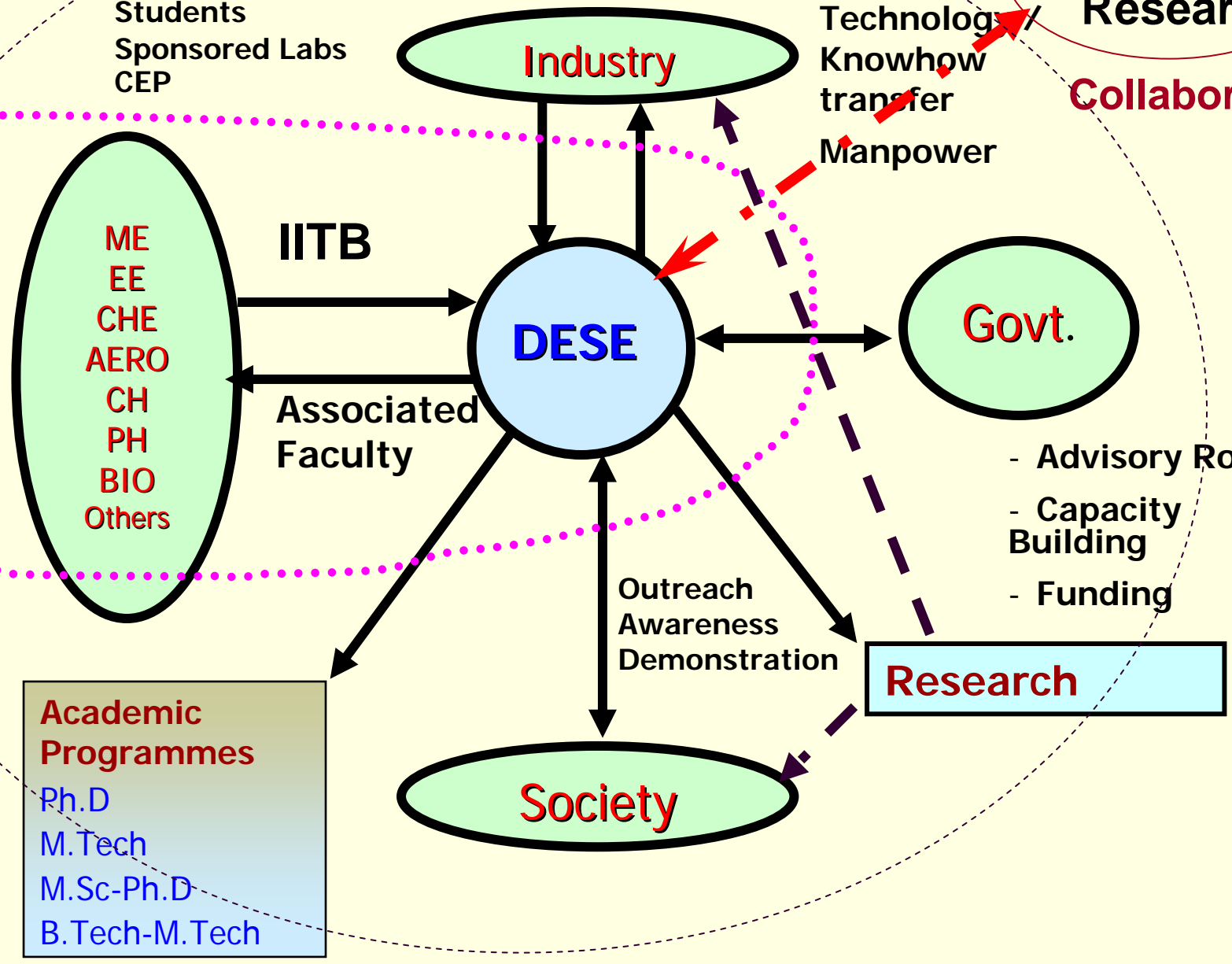


**UK**  
**Research**

**Collaborate ?**

Sponsored projects  
Sponsored  
Students  
Sponsored Labs  
CEP

Technology/  
Knowhow  
transfer  
Manpower



**IITB**

**DESE**

**Govt.**

**Associated  
Faculty**

ME  
EE  
CHE  
AERO  
CH  
PH  
BIO  
Others

Outreach  
Awareness  
Demonstration

**Society**

**Research**

- Advisory Role
- Capacity Building
- Funding

**Academic  
Programmes**

Ph.D  
M.Tech  
M.Sc-Ph.D  
B.Tech-M.Tech





# India and UK (2005 Statistics)



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

# 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:

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**Thank you**