



**narec**



*Accelerating Technology Commercialisation*

## **Silicon Solar Cell Technology**

*Keith Heasman - Senior Scientist - PVTC*

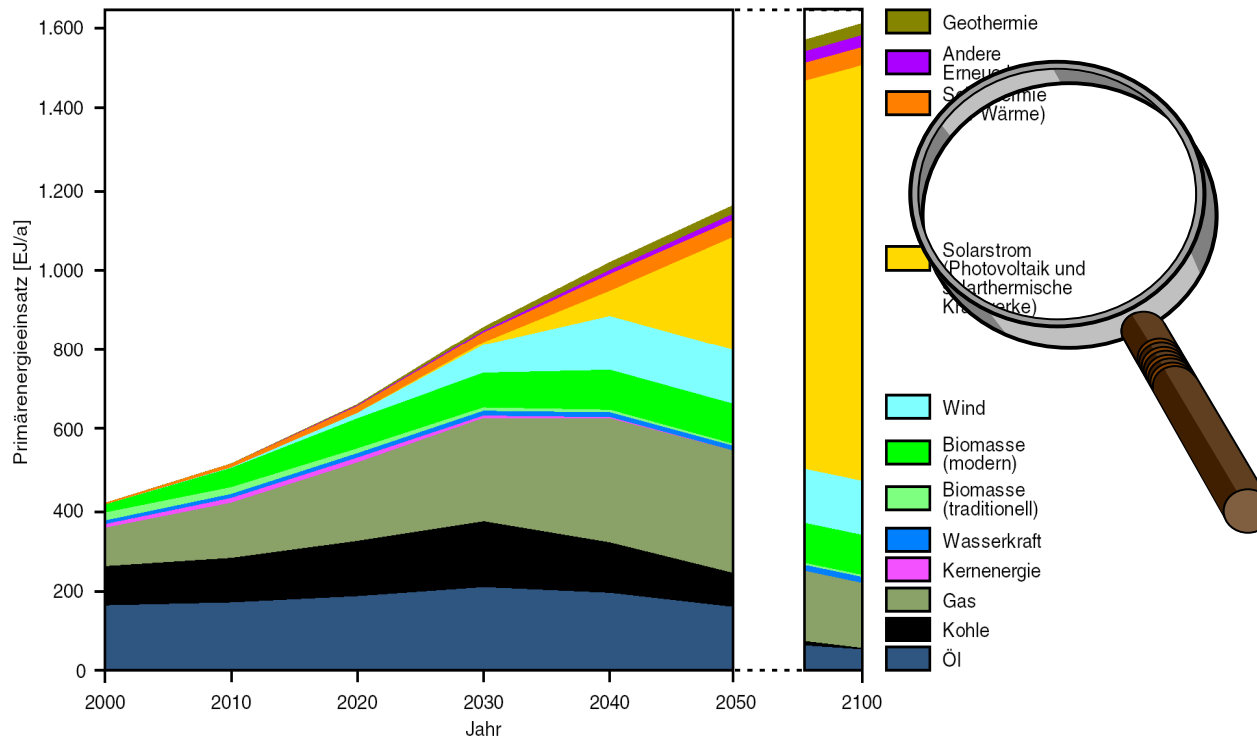
## Outline

- PV Market
- Silicon PV Technology
- Concentrator Cells
- Narec PV Capabilities
- New Technology
- Conclusions

## Advantages of PV

- No emissions of noise or fume
- No moving parts - low maintenance
- Largest renewable energy resource
- Scalable from mW to GW
- Readily adapted into the urban environment

# Solar energy and the energy transition



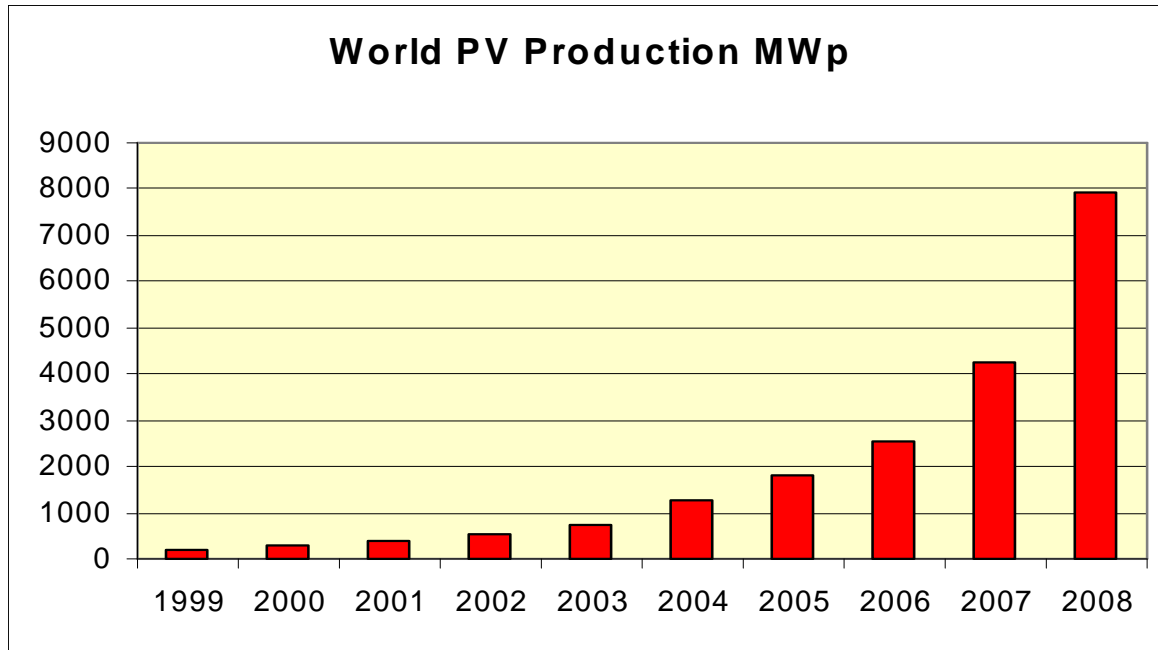
Advisory Council  
to the German  
government on  
global climate  
change WBGU  
(2003)

**Abbildung 4.4-3**

Energieeinsatz nach Energieträgern für den exemplarischen Transformationspfad. Dieser Pfad demonstriert, dass der nachhaltige Umbau der globalen Energiesysteme technologisch möglich ist. Ein anderer Technologiemitmix bei den erneuerbaren Energien könnte dies ebenfalls leisten.

Quelle: WBGU

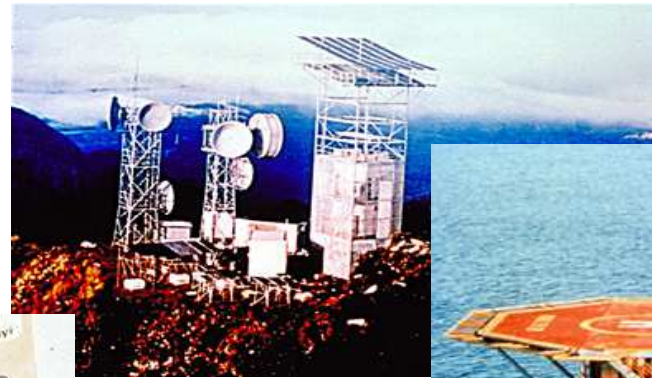
# World Market Growth



Rapid growth

58% annual growth rate since 1999

# Applications – Off grid cost effective



## On Grid- Subsidy driven



## Feed-in Tariffs

- In July 2009 Ed Miliband announced a UK Feed-in Tariff  
Up to 41.3p / kWh

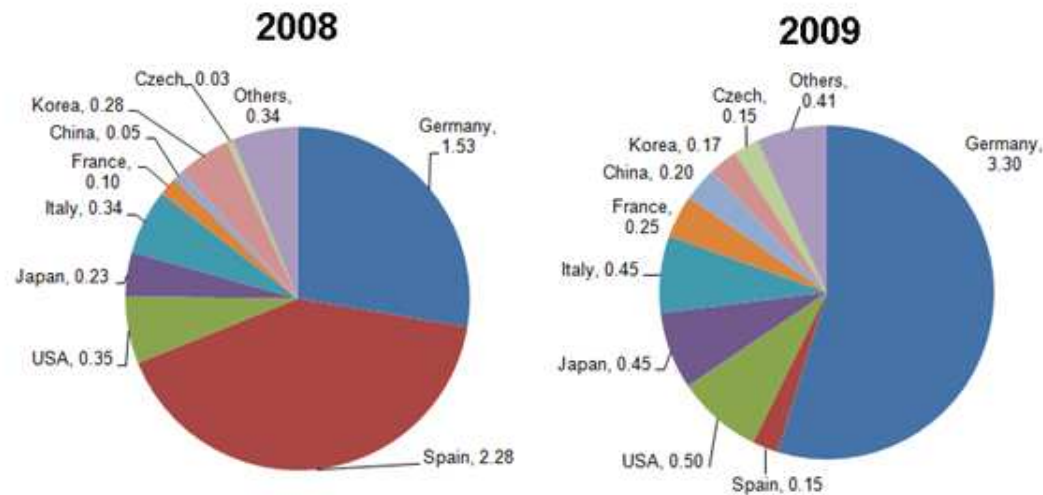
- In 2007 & 2008 Spain announced a royal decree for PV feed-in tariffs, and in Sept 2008 tariffs were reduced due to over demand

Building Integrated                      31 to 34c€/kWh <2MW.

Non Integrated                              32c€/kWh < 10MW

# 2008 / 2009 World Market

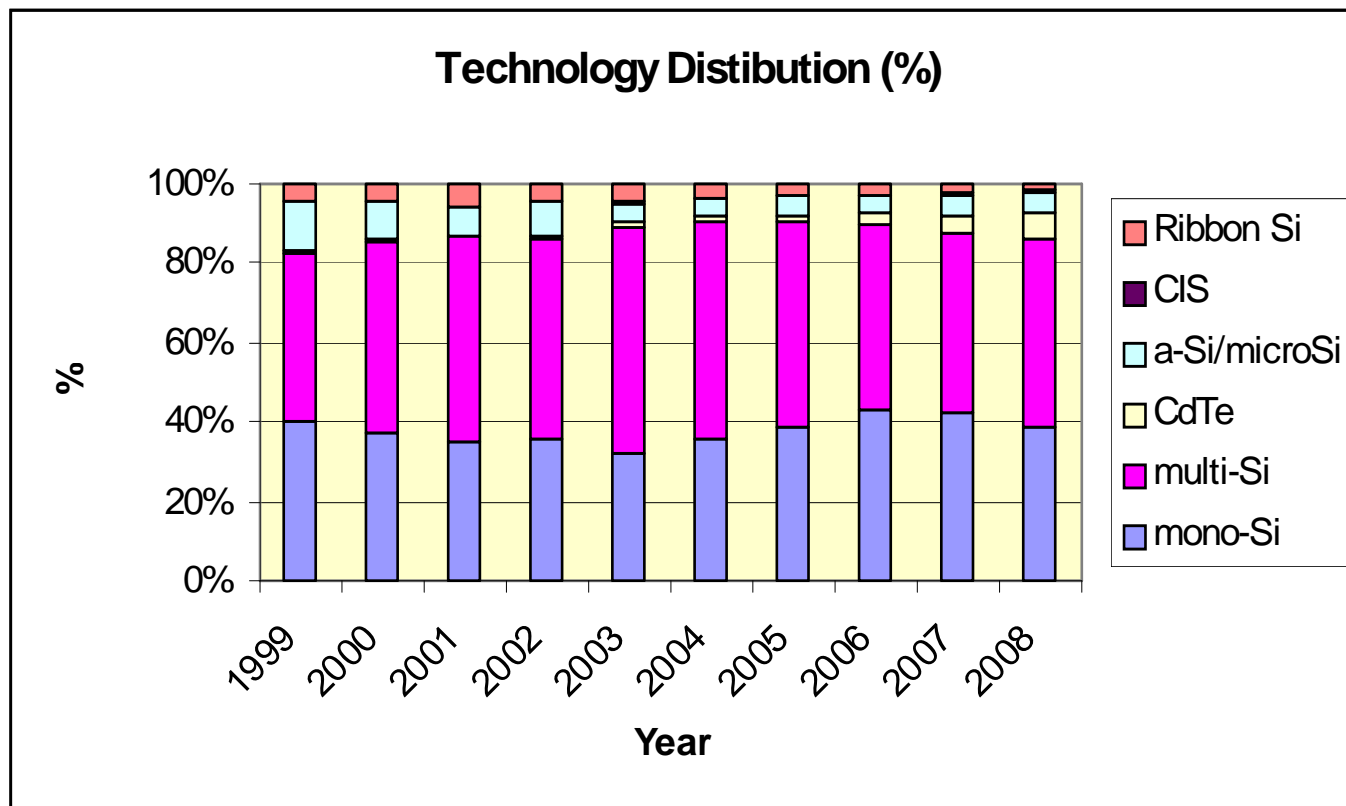
2008~2009 PV Installation Market Size by Country



(Unit GW)	Germany	Spain	USA	Japan	Italy	France	China	Korea	Czech	Others	Total
2008	1.53	2.28	0.35	0.23	0.34	0.1	0.05	0.28	0.03	0.34	5.53
2009	3.3	0.15	0.5	0.45	0.45	0.25	0.2	0.17	0.15	0.41	6.03
Market Share(2009)	54.8%	2.5%	8.3%	7.5%	7.5%	4.1%	3.3%	2.8%	2.4%	6.8%	100.0%

(Source : Displaybank, Jan. 2010)

# Technology Trend

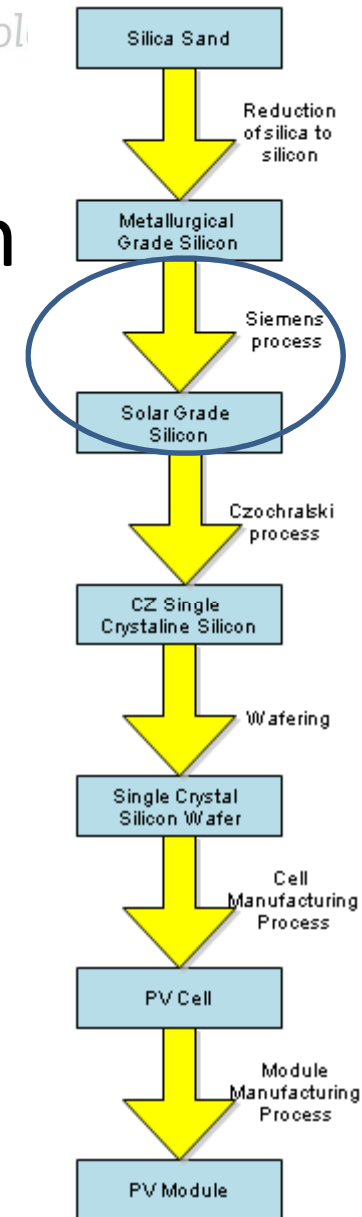


# Shortage of Solar Grade Silicon

- Silicon is purified to 99.99999% purity using the Siemens process.
- Rapid growth in PV lead to a global shortage



Polycrystalline rod produced by Siemens process



## First Solar Inc CdTe module Technology

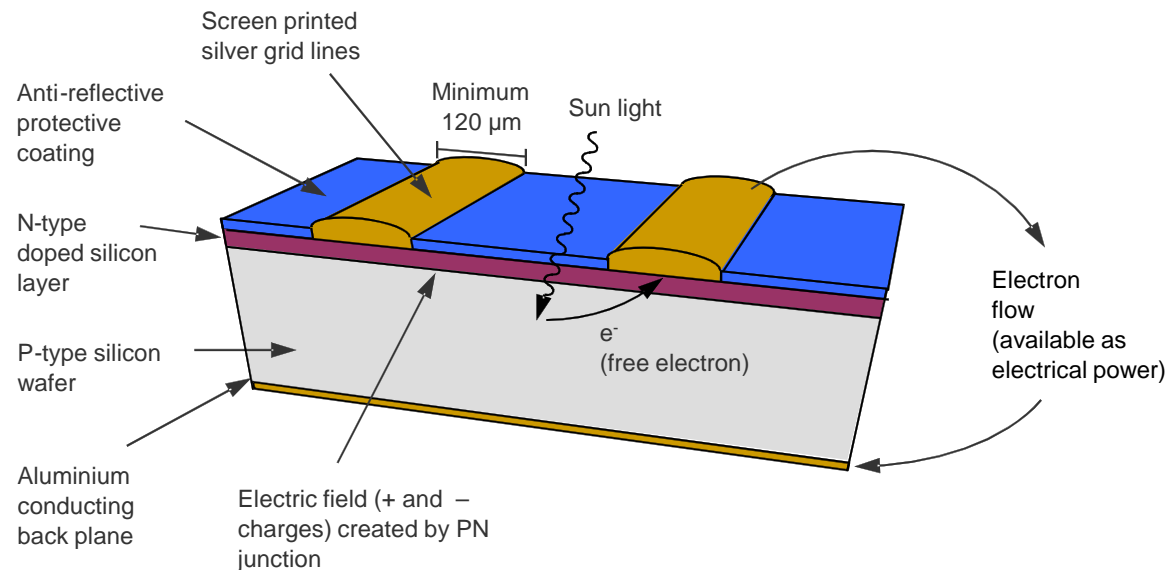
- Aiming towards 10 % module efficiency
- Scaling up to 1 GWp p.a. production
- Manufacturing cost less than \$1/Wp



## Leading Manufacturers (2008)

Company	Country	Production (MWp)
Q Cells	Germany	582
First Solar (CdTe)	USA	504
Suntech	China	498
Sharp	Japan	473
JA Solar	China	300
Kyocera	Japan	290
Yingli	China	281
Motech	Taiwan	272
SunPower	USA/Philippines	237
Sanyo	Japan	215

# Typical mass-produced solar cell

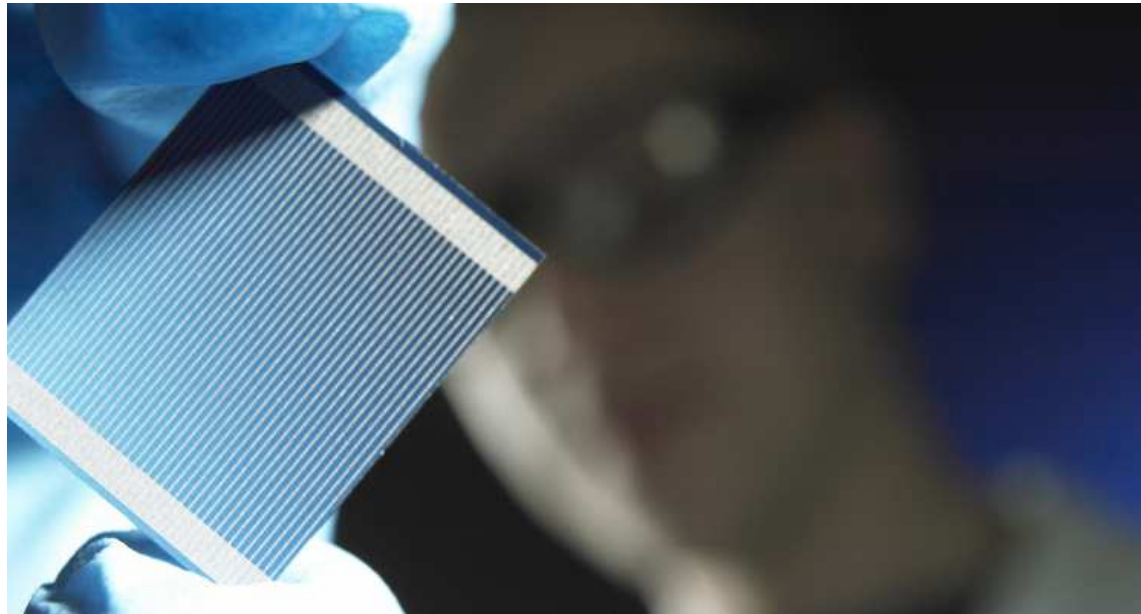


Advantages: Simple Process / Low Manufacturing Cost

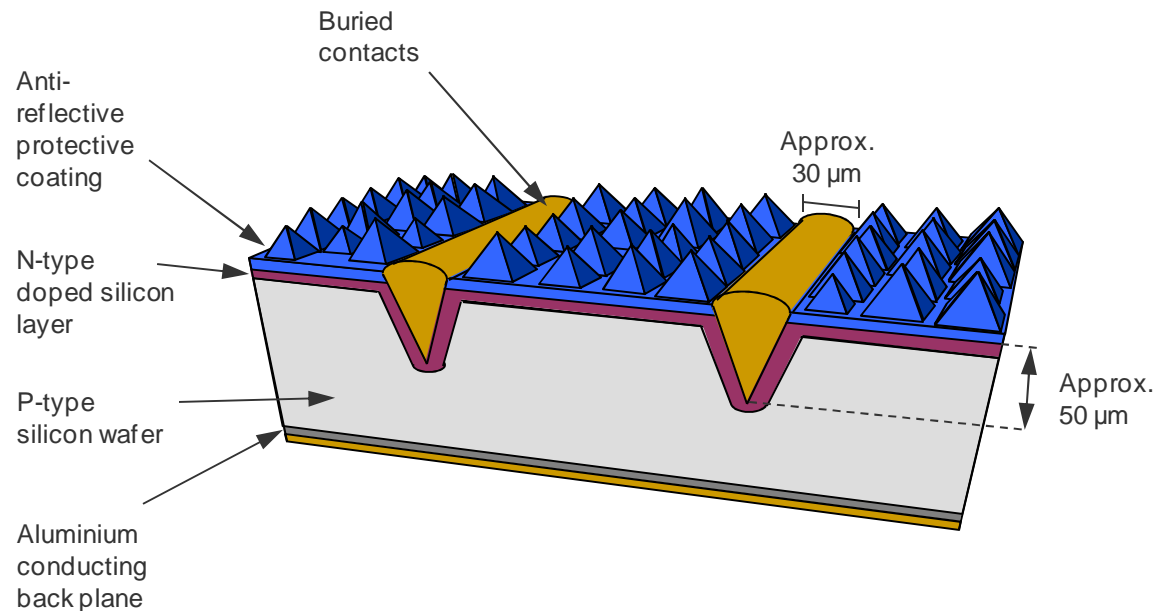
Disadvantages: Wide Grid Lines / Non Optimum Homogeneous Emitter / Process not suited to thin wafers

## What we do at Narec

- Small scale production of bespoke solar cells
- Public funded research and development
- Private funded research and development
- Consultancy on PV technology and markets



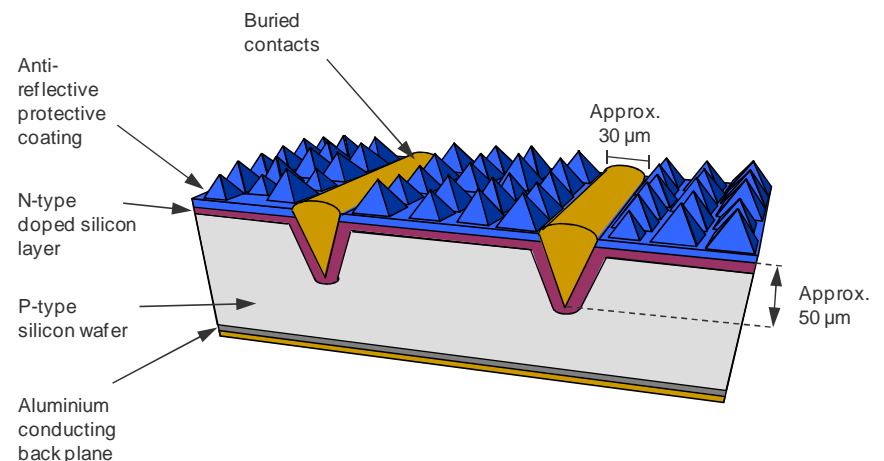
# Laser Grooved Buried Contact Solar Cell



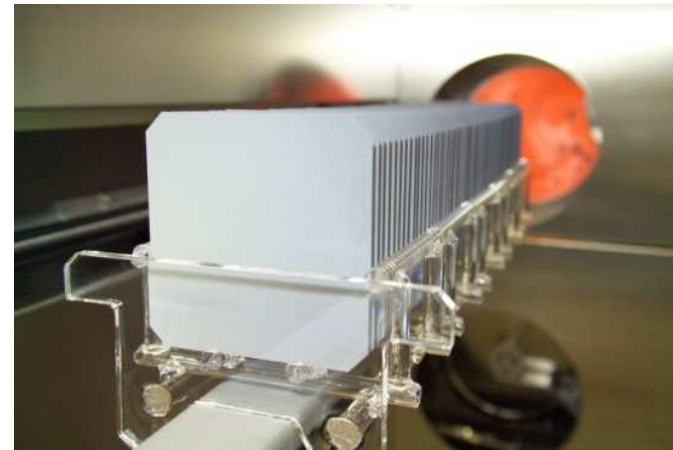
- Advantages:**      Narrow, highly conducting grid lines / Selective Emitter / Higher Efficiency / Electroless Plating
- Disadvantages:**      Slower / more complicated process

# Solar cell fabrication process

- Saw damage removal (wet etching)
- Texturisation (wet etching)
- Emitter formation (phosphorus diffusion)
- Laser Grooving
- Groove Etch
- Selective emitter formation (heavy phosphorus diffusion)
- Al sputtering and sintering
- Electroless chemical plating
- Laser isolation

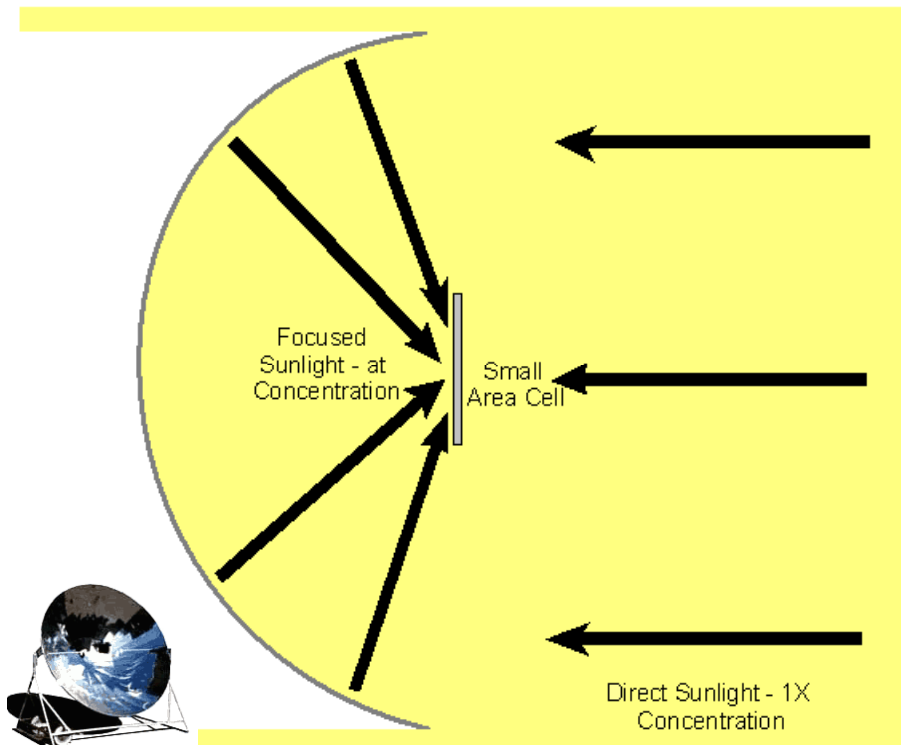


# Narec PV Process Equipment

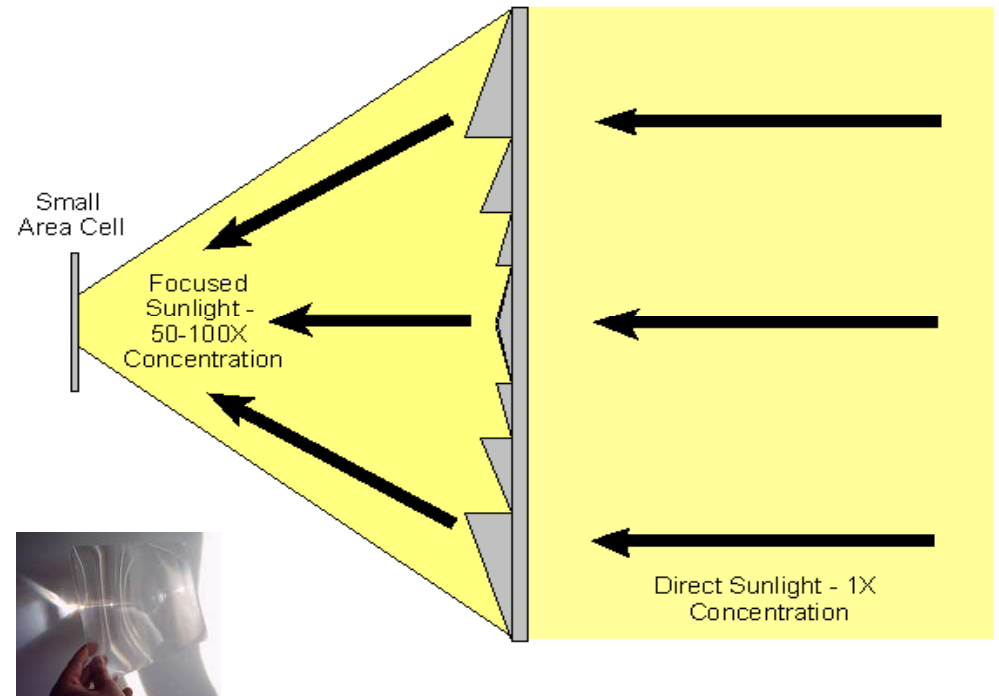


# Concentrator Systems

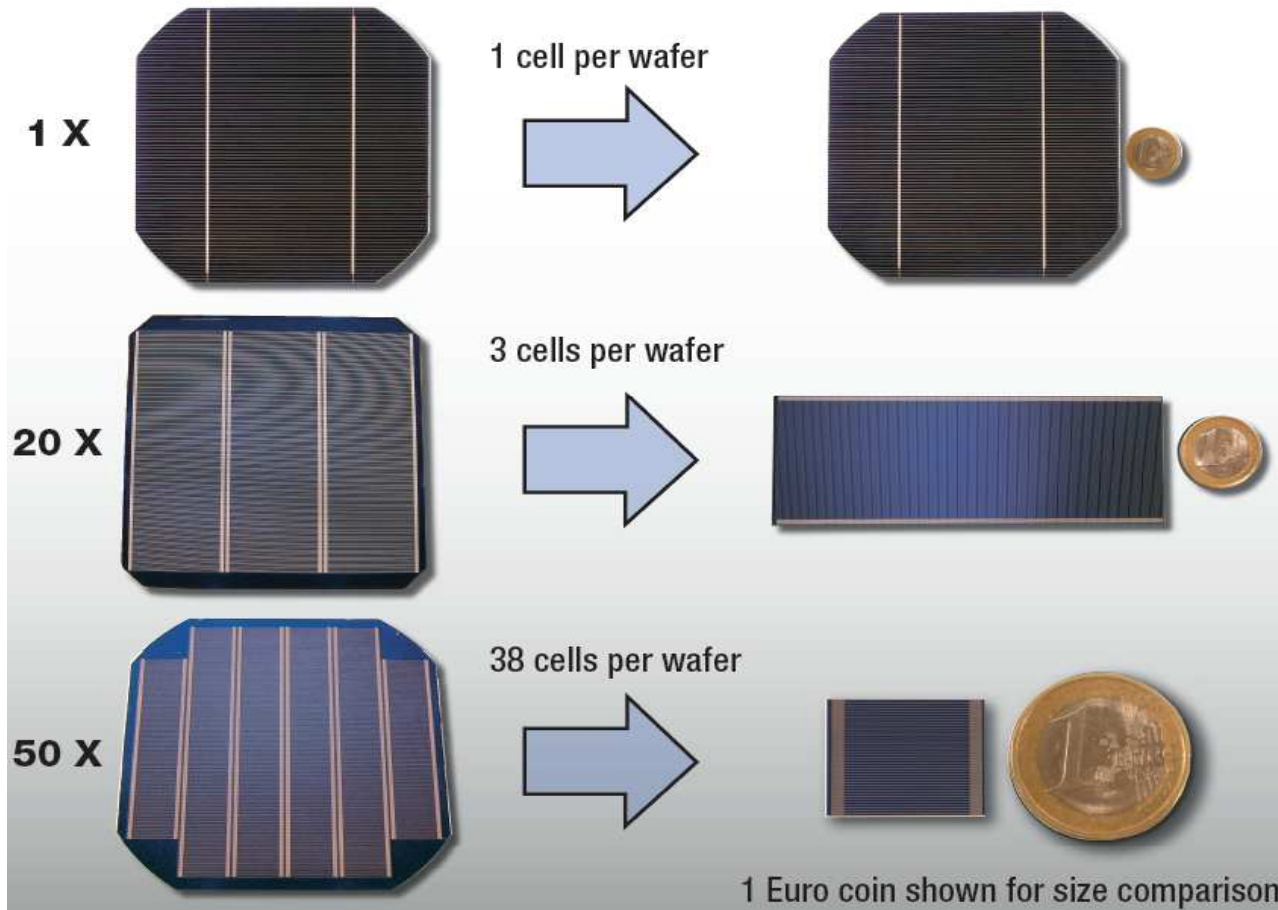
Parabolic Mirror Concentrator System



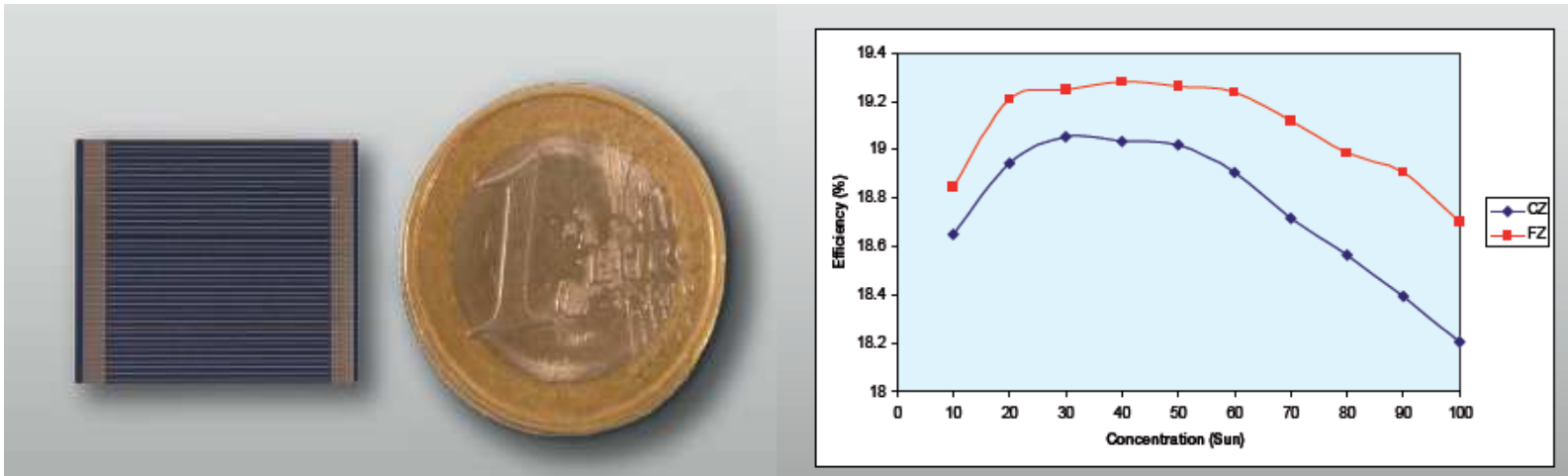
Fresnel Lens Concentrator System



Concentrator systems are a potential solution to low cost power generation

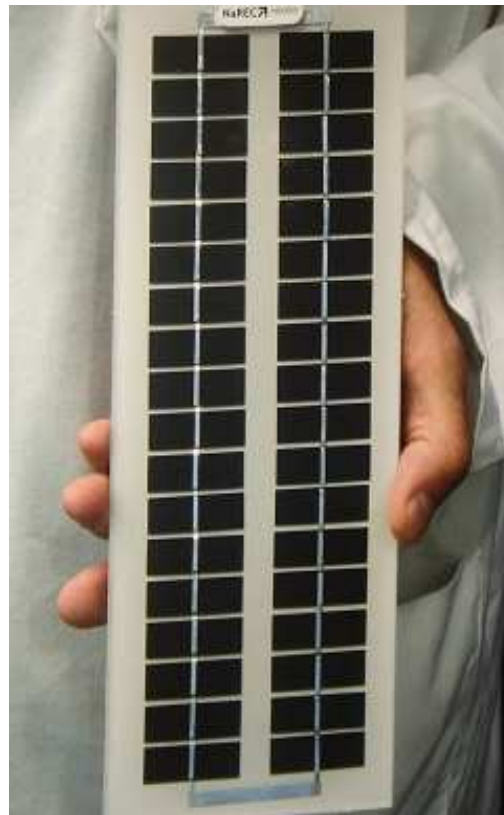


## Cells Optimised for 50X Concentration



Cells and system designed as part of the DTI funded LUCENT project

# Highways Agency Mini Modules



## Current Narec R&D Projects

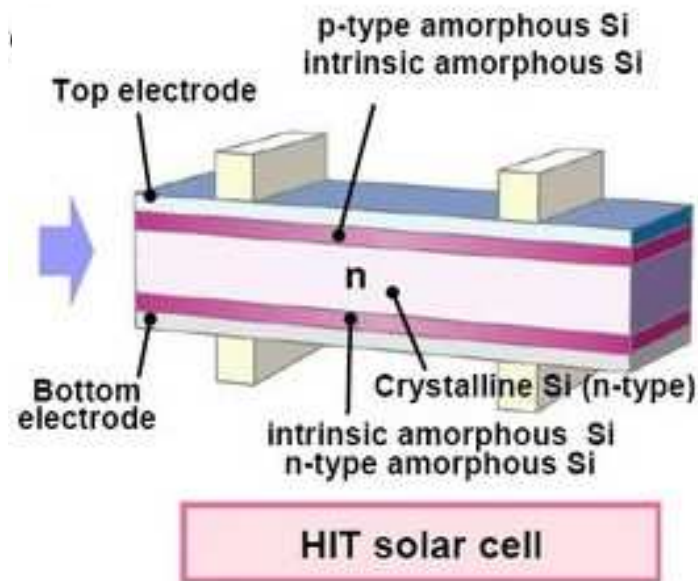
### EU Funded

- LAB2LINE                      LGBC /Screen Print hybrid cell technology
- APOLLON                      Low cost concentrator systems
- ASPIS                          Low concentration silicon modules

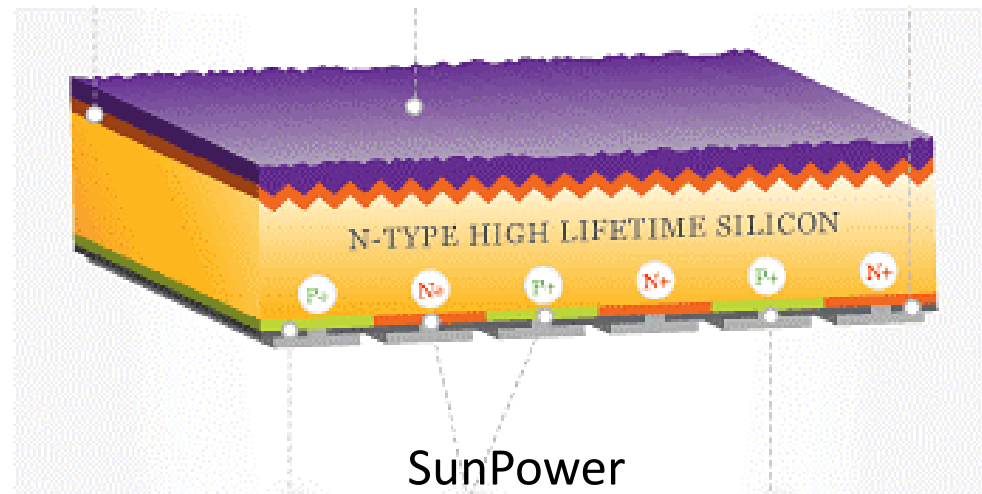
### UK Funded

- HIGHPOINT                      High Efficiency Silicon LGBC Cells
- III-V CPV                      Multijunction concentrator systems

# Other silicon cell technologies



Sanyo  
High Efficiency  
Bifacial cell structure



All back contact cell structure  
High Efficiency  
Uniform front side appearance

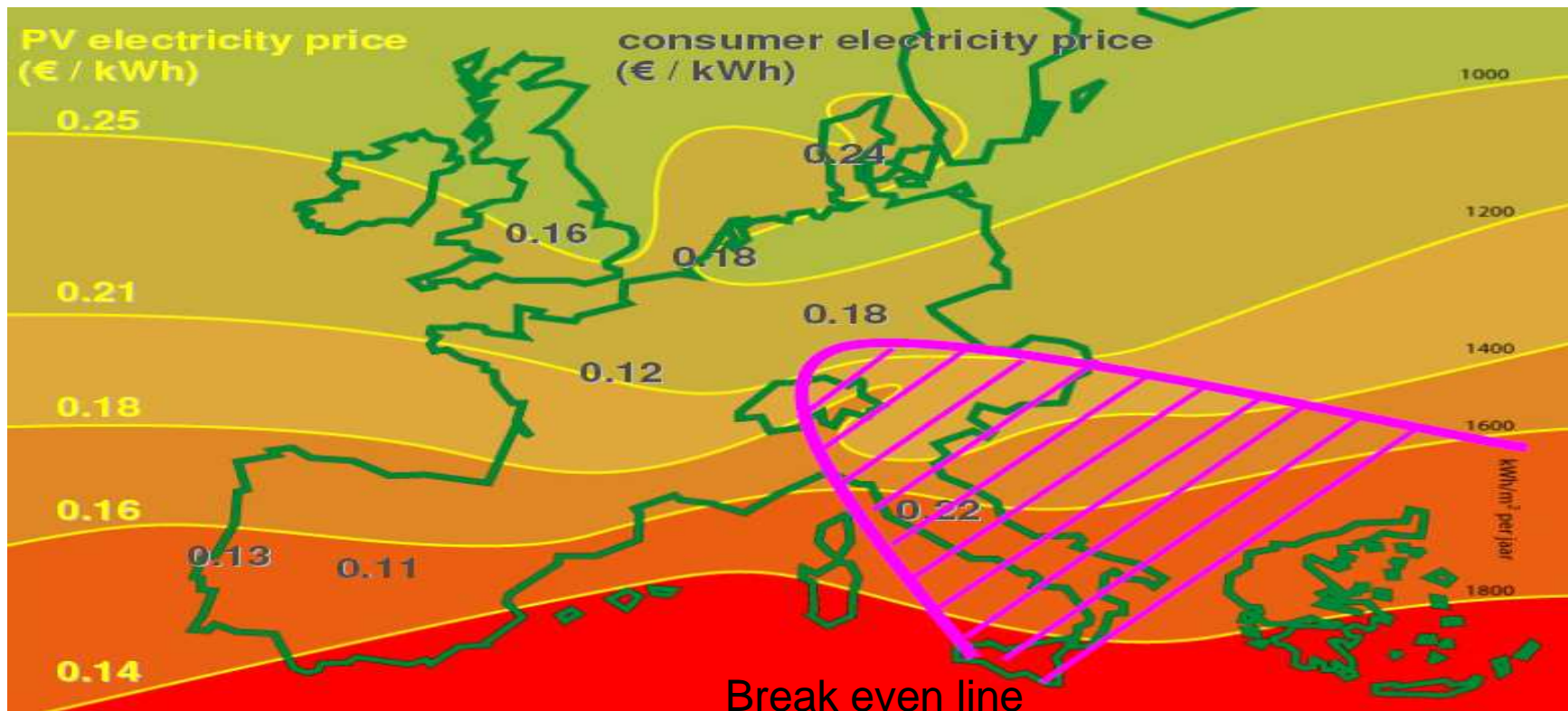
## Why look for new technologies

- PV market driven by cost per Wp
- PV needs to achieve grid parity to be competitive with fossil fuels (unless government intervenes e.g. feed in tariffs )

Therefore there is a need to

- Increase Efficiency (increase Wp)
- Lower Production Costs
  - Drive towards thinner and thinner silicon wafers

## Why new technologies (2)



New and Renewable Energy Centre  
[www.narec.co.uk](http://www.narec.co.uk)

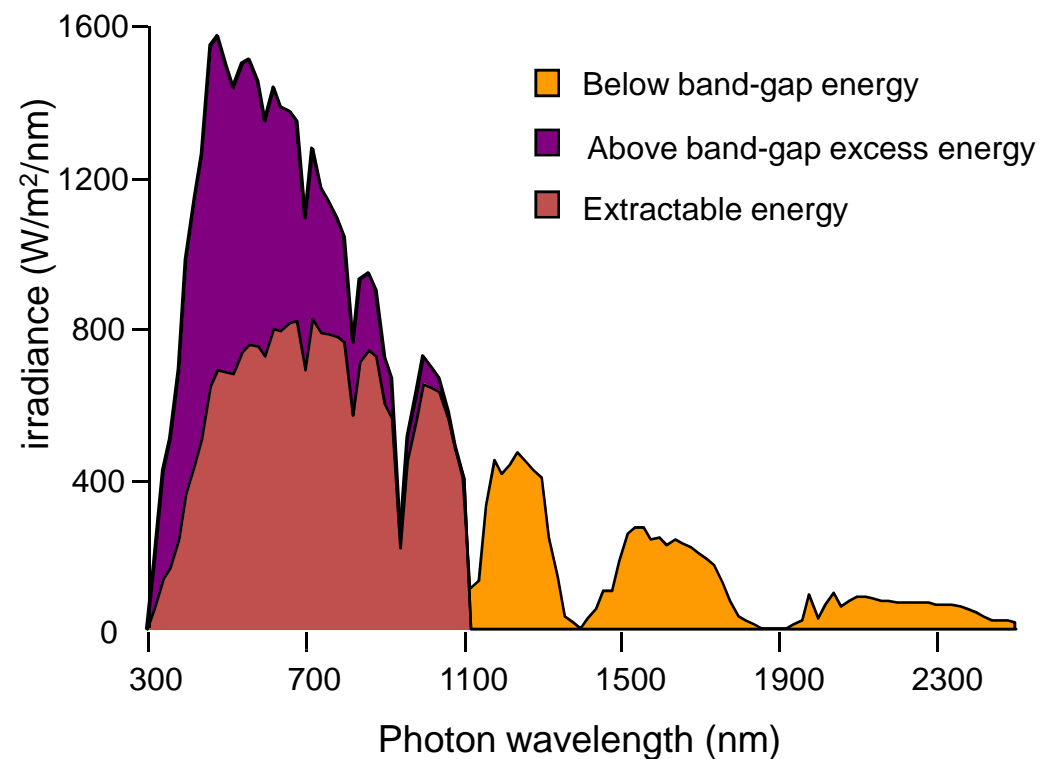
From EU PV platform 2005

2015

# Limits of Silicon Solar Cell Performance

Theoretical efficiency approximately 30% limited by the properties of silicon

Practical cell efficiency is limited further due to reflection, absorption, resistive and recombination losses



## EXTRACTABLE ENERGY FROM THE SOLAR SPECTRUM

## New Technologies

- Wider use of the solar spectrum
- Multilayer tandem devices
- Spectral Splitting
- Intermediate band gap devices
- Hot electron devices
- Frequency up and down conversion layers
- Nanotechnologies – quantum rods & dots

## Continued Drivers for Growth

- Grass roots opinion in Germany for PV
- PV is a long term strategy in Japan
- Large growth potential in China and India for off-grid
- Additional countries adopting successful feed-in tariffs  
Greece, Italy, other US states, UK.
- High oil prices, uncertainty of supply, concern over global warming.

## Summary

- Continuous cost reduction essential
- Silicon technology dominant in short and medium term
- Thin film technologies particularly CdTe becoming significant
- Concentrator technology can increase efficiency and reduce cost of electricity
- Long term growth potential in PV

# Thank you

Presentation prepared by  
Keith Heasman  
Alex Cole  
Steve Robert  
Tim Bruton

# Full List of Narec PV Capabilities

## Silicon Wafer Analysis

- Minority carrier lifetime measurement
- Impurity Analysis (interstitial Oxygen and Substitutional Carbon)
- Wafer thickness and total thickness variation
- Bulk Resistivity

## Silicon Wafer Processing

- A pilot production line for the Laser Grooved Buried Contact Solar cell including
  - Wet chemical and plasma etching: Alkaline and acid etching, wafer texturisation (alkaline texturisation).
  - Phosphorous diffusion
  - Laser patterning / scribing / cutting / edge isolation
  - LPCVD silicon nitride
  - Electroless metal plating and sintering
- Solar cell characterisation
  - 1Sun production cell tester
  - Cell tester for measurement up to 100Sun concentration
  - LBIC mapping capability
  - Sheet resistance mapping capability
  - Reflectance mapping capability
  - QEint / QEext mapping capability
  - Dielectric layer thickness, refractive index measurement
  - Metallisation analysis
- Solar Module manufacturing capability
  - Narec currently manufactures 2W modules for emergency roadside telephones.
  - Narec is capable of producing niche modules for a variety of applications.
  - Cell tester for measurement up to 100Sun concentration
  - Environmental test chamber