當紅炸子雞 – 太陽能

Pin Ho

February 10, 2010

Outline

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- 背景
- 太陽能電池總類
- 產品應用
- 生產製造介紹
- 營業與成本分析
- 自由討論

Pin Ho, Ph.D. – University of Illinois at Chicago

- **KITH Energy Ltd.**, CTO
  - CIGS thin film cell/module technology
- **Sunshine PV Corp.**, R&D Director
  - CIGS thin film cell/module R&D and process engineering
- **AdvanSolar Inc.**, President
  - module design and application based on III-V solar cells
- **RFIC Technology**, Vice President, Marketing and Sales
  - rf integrated circuit design for wireless communication
- **Xpert Semiconductor**, President and CTO
  - compound semiconductor epitaxial wafer growth for wireless communication, optoelectronics and photonics applications
- **Global Communication Semiconductors**, Co-Founder and Vice President of EPI Operation
  - compound semiconductor wafer foundry and epitaxial wafer merchant
- **General Electric** and **Lockheed Martin**, Principal Staff
  - microwave electronics design and production for warfare
- **Varian Associates**, Senior Research Engineer
  - GaAs based solar cells and charge-coupled devices conceptual design and prototyping

背景

能源之母

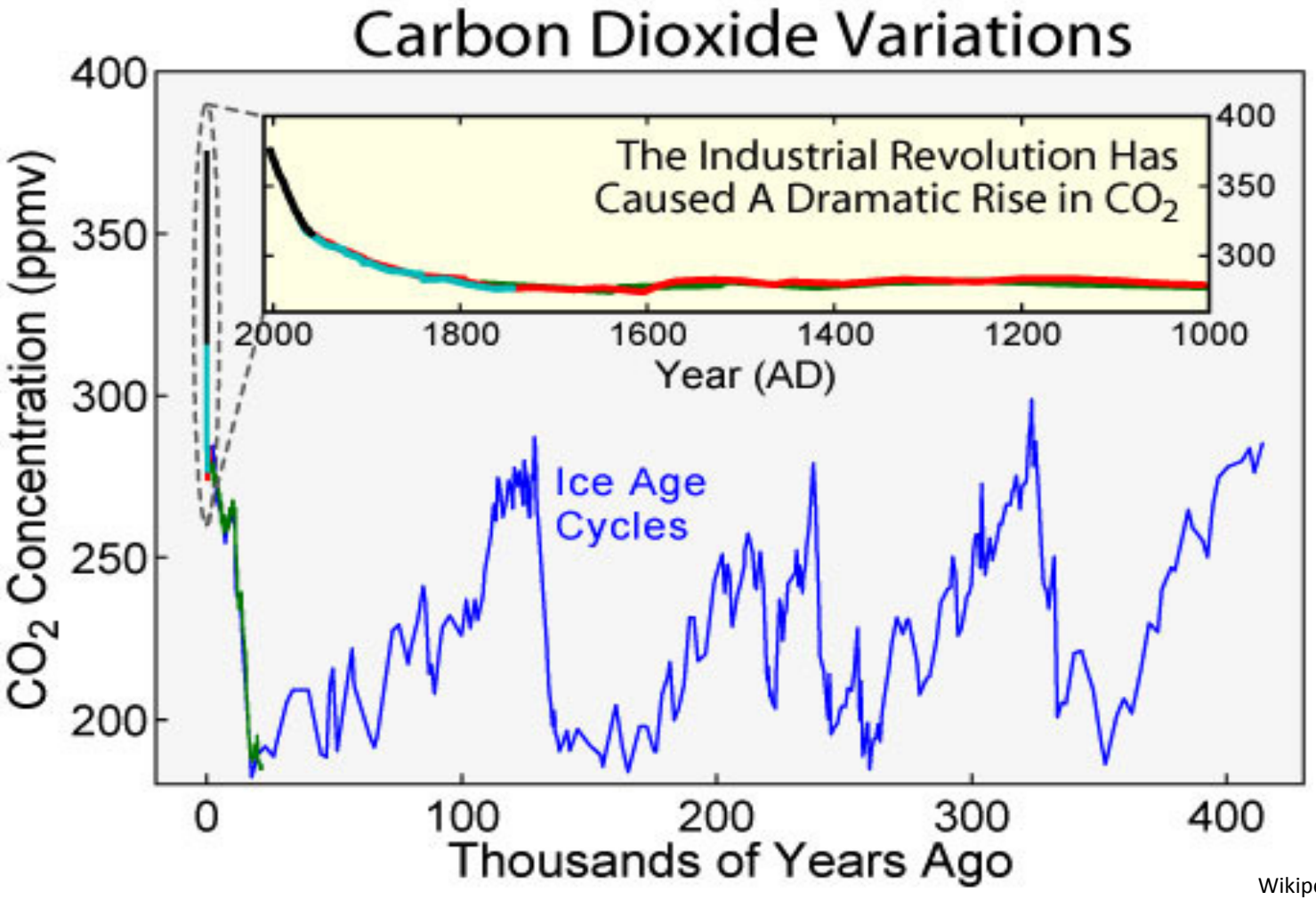
- 傳統能源漸漸枯歇，替代能源興起
- 環保意識興起，節能減碳
- 太陽光能照射在地表一小時的能量(≒5×10^{20}J)，可供我們全人類一年的用量
- 太陽至少還能照射地球”50億年”以上
- 太陽能是免費，取之不盡，用之不竭之潔淨能源，但必須找到有效的使用方法

背景

- 哥本哈根會議共識，確認全球需要控溫攝氏2度
  - 中國作爲第2大碳排放國，承受的國際壓力和責任都促使中國不得不改變現有的能源結構
- 新能源引領的綠色產業革命
  - 將大大改變現有的工業結構和消費觀念，有望成爲後金融危機時代的經濟發展新引擎
- 各國政府對於再生能源的扶持政策
  - 爲初創期的產業提供優異的環境和引導方向
- 投資力度增強，融資渠道拓寬
  - 從研究開發、工業放大到量產的各階段都可獲得充裕的資金支持

新興能源從小規模高速發展，過渡到大規模高速發展階段

CO_2 Level 改變



Wikipedia

CO_2 改變

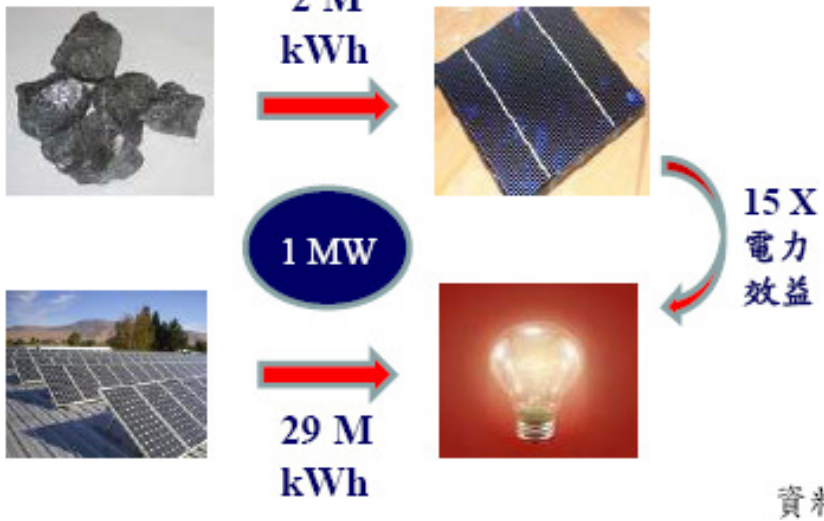
- The latest review affirms that atmospheric CO2 concentration — now at 385 ppm — is rising at a rate of 2.5 ppm a year.

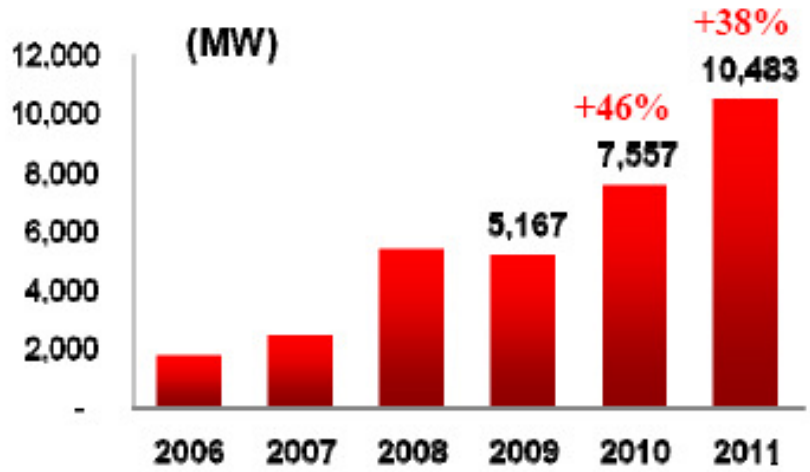
- It has generally been believed that a CO2 level of 450 ppm is the danger point beyond which catastrophic and irreversible climate change might occur.

For example: For every 1-degree Celsius increase in temperature, ocean oxygen levels are said to decline by about 6%.

背景

- 產出1 MW需花費 2M度電力，但1 MW太陽能20年可生成29 M度電力，相當具節能性
- 受惠全球景氣回溫，除了各國講求節能議題，許多國家力推太陽能，其中中國、義大利、美國為太陽能需求成長最為快速的地區
- 除了再生能源政策補助外，少數地區太陽能發電成本接近零售電價為未來可期待潛在需求市場；ie.自發性安裝需求

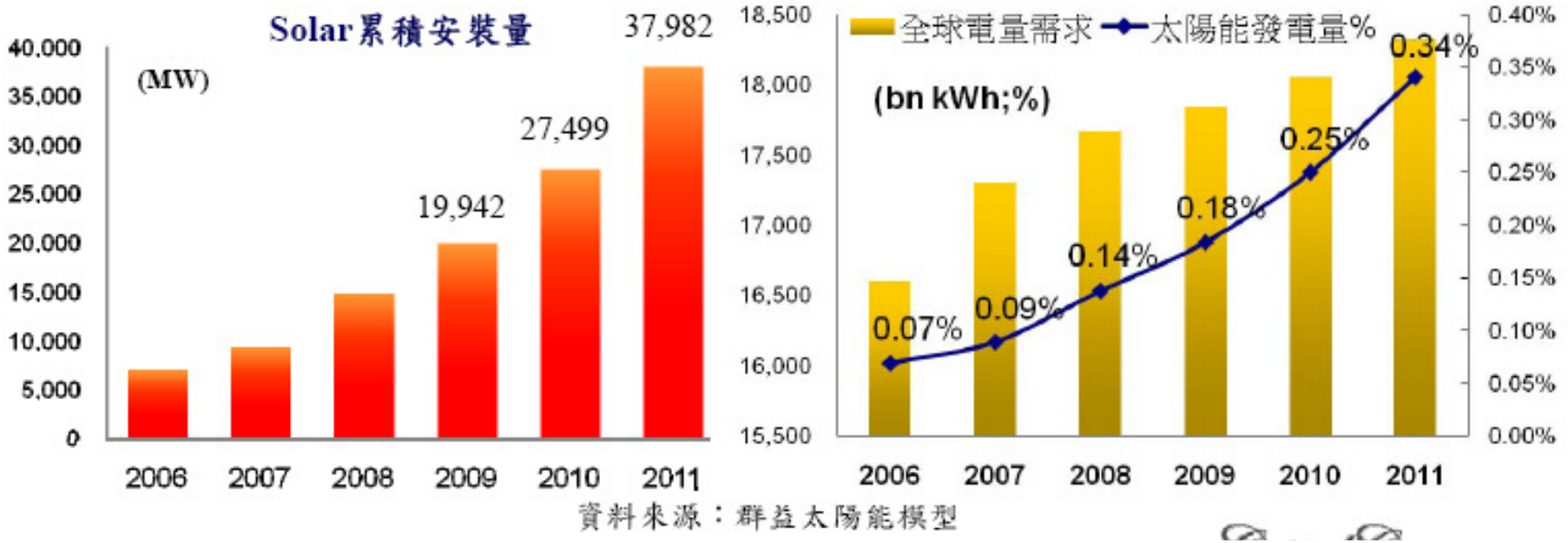




資料來源：群益太陽能模型

背景

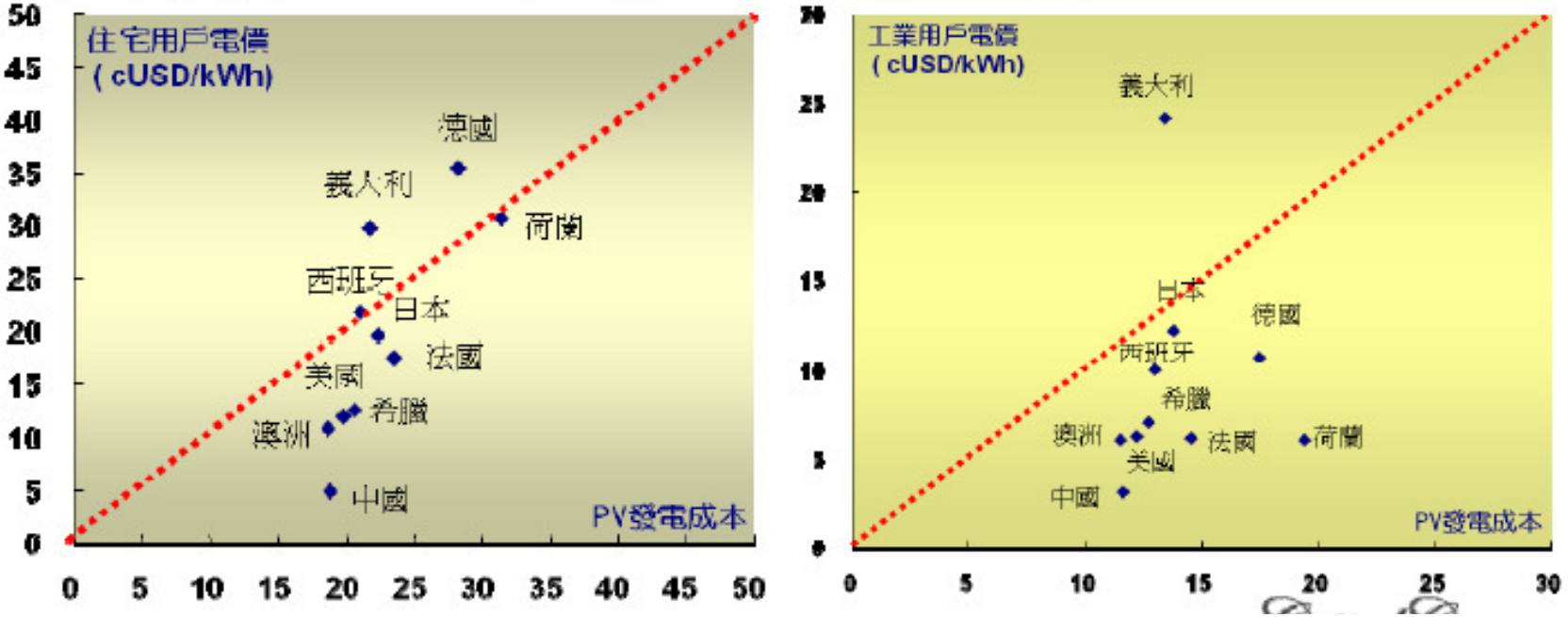
- 有鑒於火力發電高污染性，再生能源商機因應而生，現階段則以太陽能、風力及水力為替代能源解決方案
- 太陽能累積安裝量逐年增長，群益預估2010年達27.5 GW
- 全球電量需求(On-Grid)穩定增長(<5%),然群益預估太陽能發電量滲透率 < 0.3% ，顯示太陽能市場仍有其發展性



資料來源：群益太陽能模型

背景

- 2008年下半年至今太陽能價格暴跌(3.5美元/W降至1.3美元/W)，有助於刺激安裝需求
- 倘若約當設備使用年限二十年，依各國不同日照度可得住宅用戶自發性安裝相較於工業用戶來得有機會
- 基於PV系統設備成本跌價，群益預期2010年將有利觸發少數國家自發性安裝需求，如：日本、義大利、德國及西班牙



背景

- 再生能源政策除了節能減碳效益之外，培植國家重點產業發展亦是刺激景氣策略，群益預期未來陸續將有不少國家跟進發佈相關政策

- 再生能源政策(Renewable Policy)重點方向 (依效益性排序)

  (1)設備補助：補貼系統設備成本30%~50%

  (2)電價補助：根據國家電力售價,決定合理的補貼電價方案

  (3)電力回購：可分為餘電回售、全數回售

  (4)稅額優惠：給予所得稅減免優惠(等同限額的設備補助)

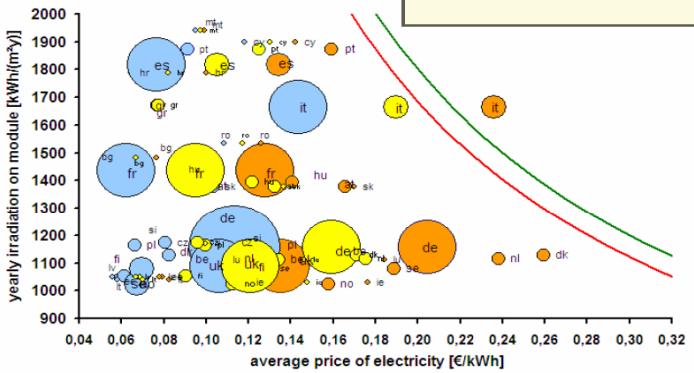
  (5)投資抵減：系統設備投資給予投資抵減或加速折舊

  (6)優惠貸款：給予優惠貸款利率

Grid Parity in Europe

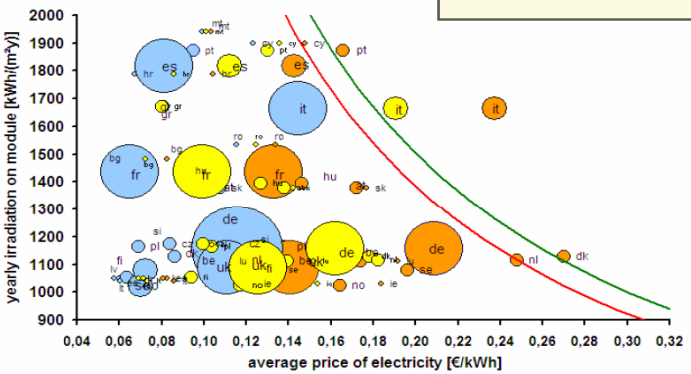
2010

Total Market: 3.162 TWh
Grid Parity Accessible Market: 74 TWh (2 %)



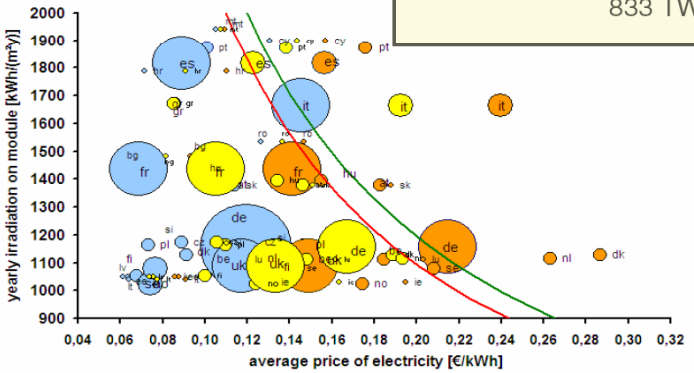
2012

Total Market: 3.286 TWh
Grid Parity Accessible Market: 208 TWh (6 %)



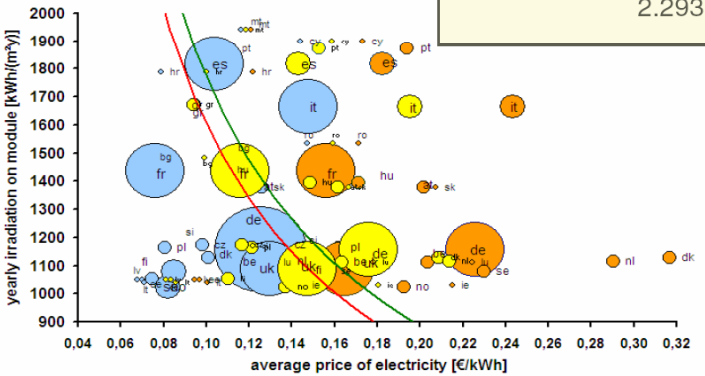
2015

Total Market: 3.484 TWh
Grid Parity Accessible Market: 833 TWh (24 %)

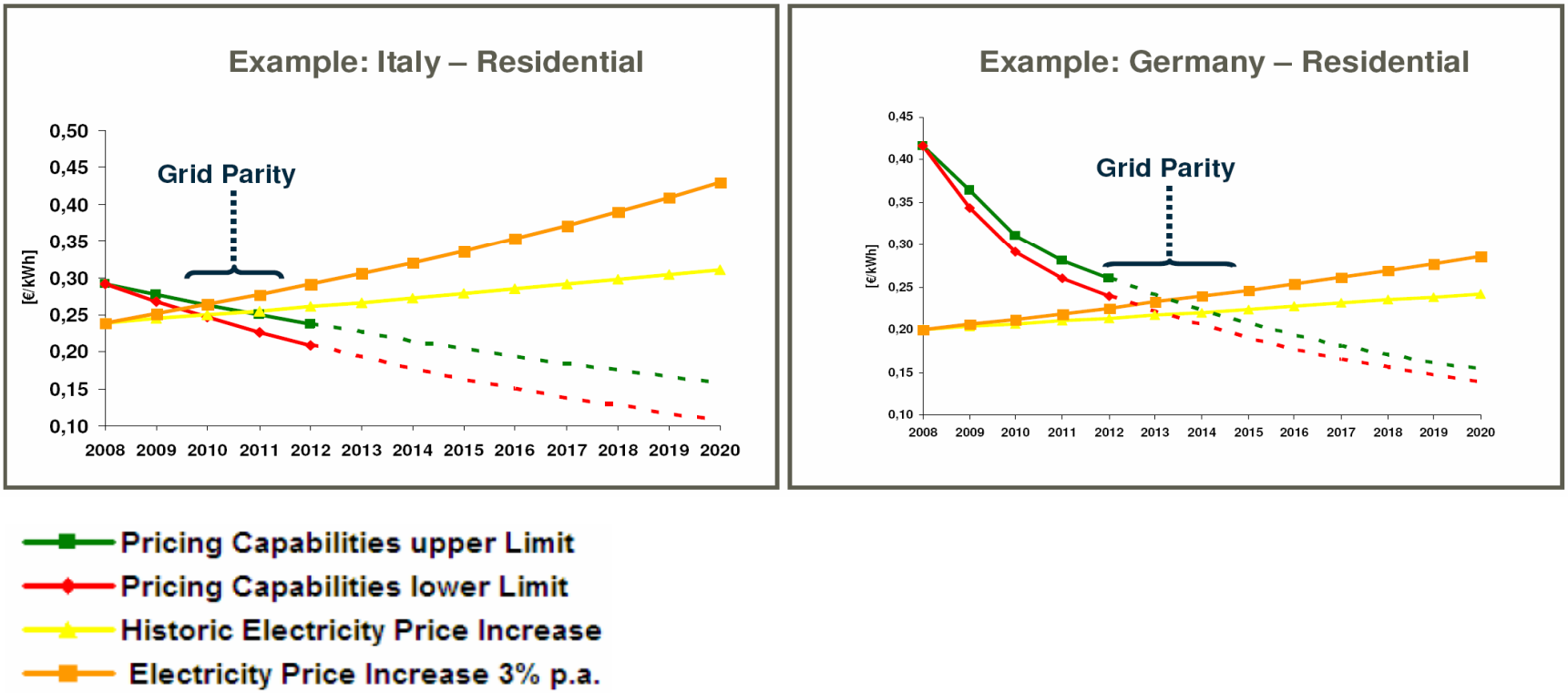


2020

Total Market: 3.857 TWh
Grid Parity Accessible Market: 2.293 TWh (59 %)

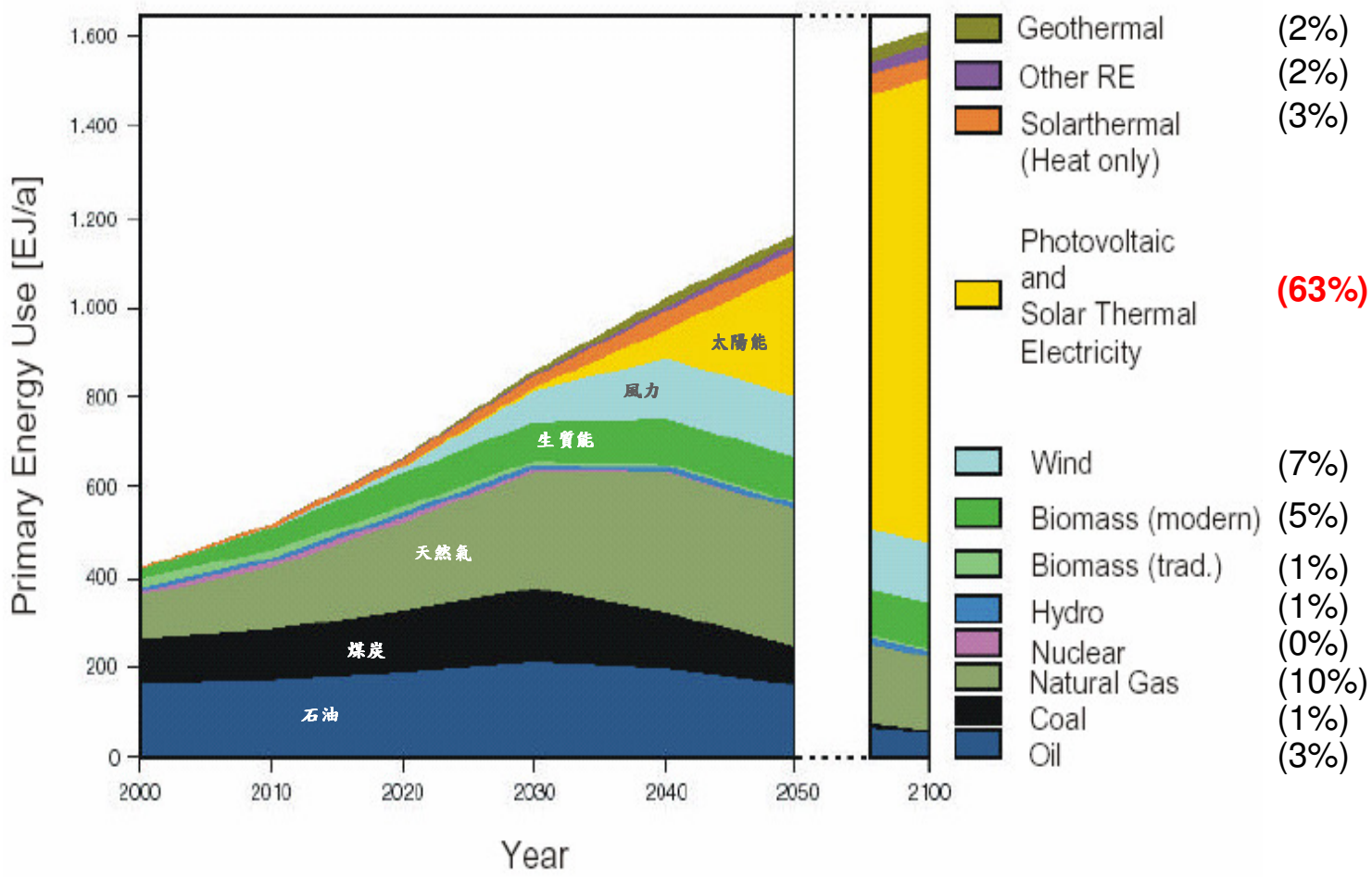


Grid Parity in Italy and Germany

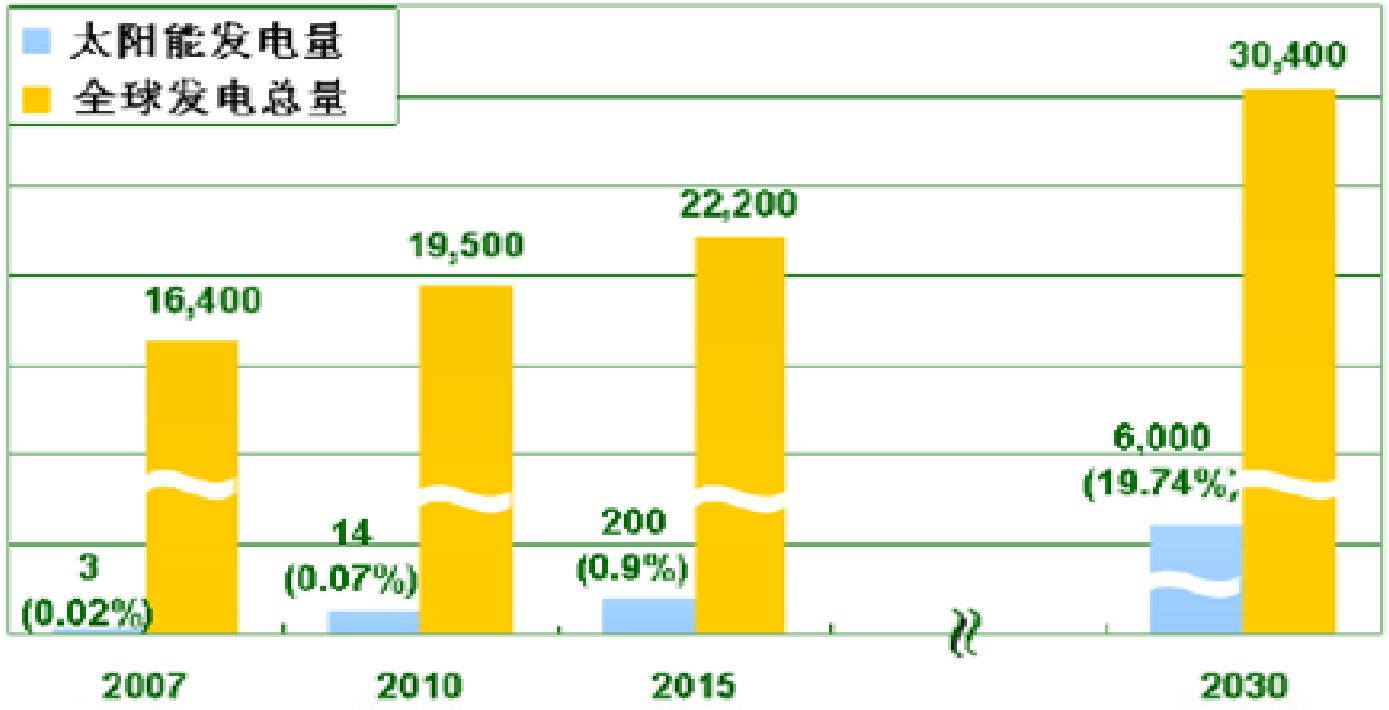


Source: Q. Cells, Inter Solar May 2009, Germany

Energy Trend



Global Trend



单位：GW

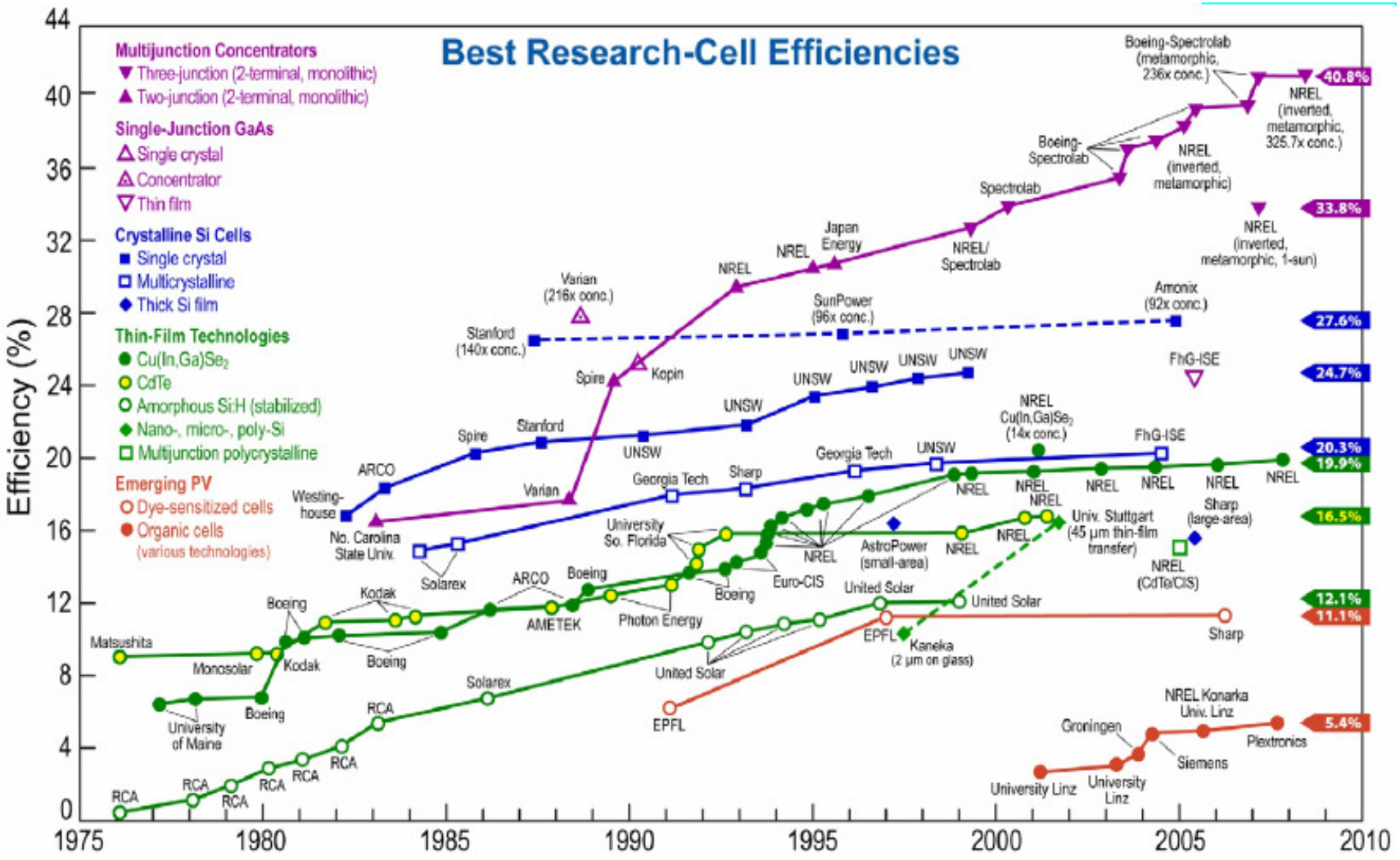
Resources：美国能源资讯管理局(EIA)

Solar Energy ~ 20% by 2030

Comparison of Solar Cells

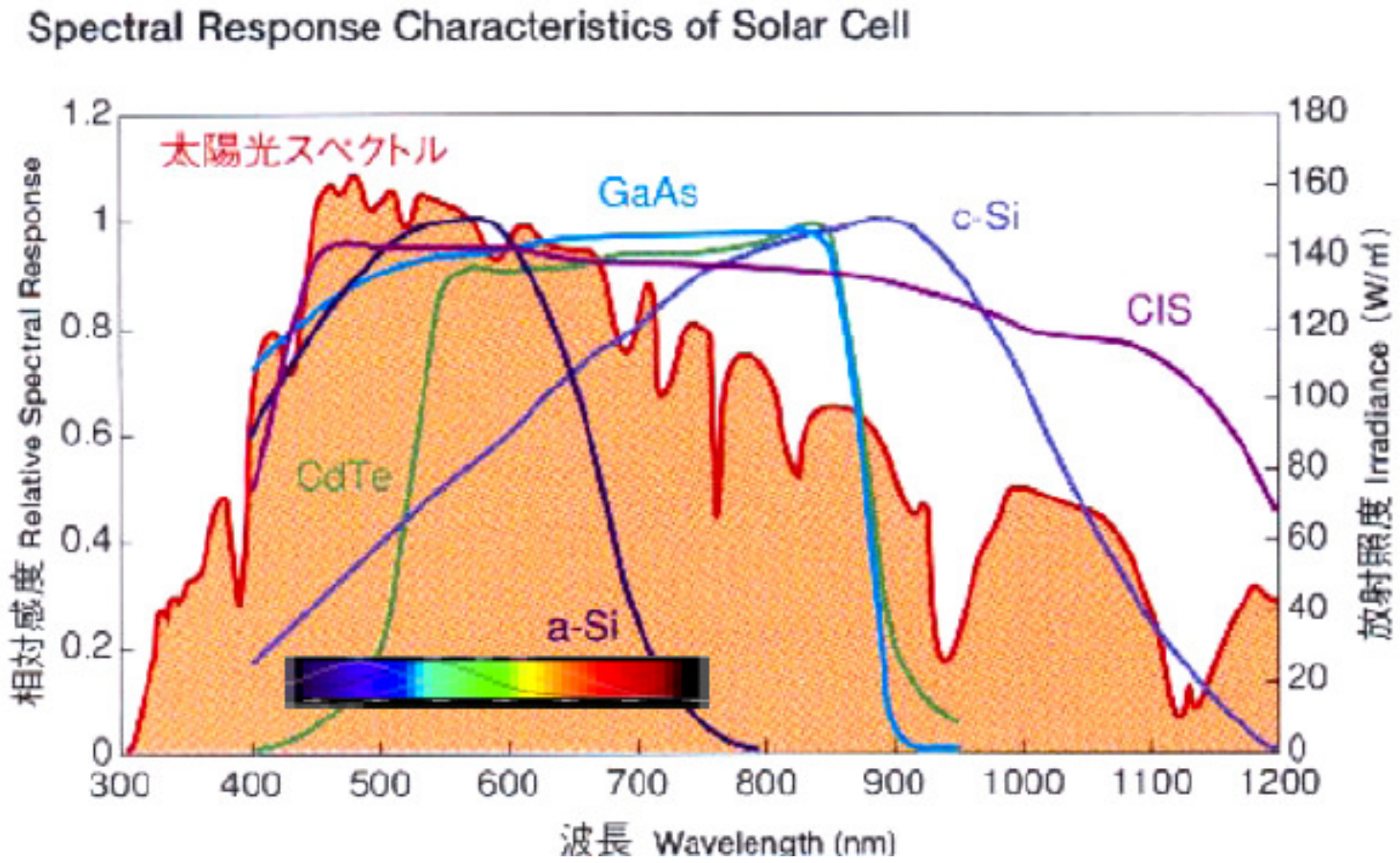
型態	種類	材料	轉換效率	需求比重
晶片型	矽	單晶矽	15~17%	35%
		多晶矽	14~16%	45%
	III-V族	砷化鎵	25.1%	
Thin Film	矽	a-Si 非晶矽	＜8.2%	20%
		微晶矽	＜10.4%	
	II-VI族	CdTe	＜10.7%	
	I-III-VI族	CIGS	＜13.4%	
電化學	有機染料	TiO_2	8~10%	-

Champion Cell Efficiencies



Source: NREL

Spectral Response



CIGS 比其他薄膜或矽晶電池有較寬的吸收光譜

Why Si-based Solar Cell

Solar cell:

- It is not a battery which can store charges
- It can only generate charges when illuminating by light

Silicon crystalline solar cell:

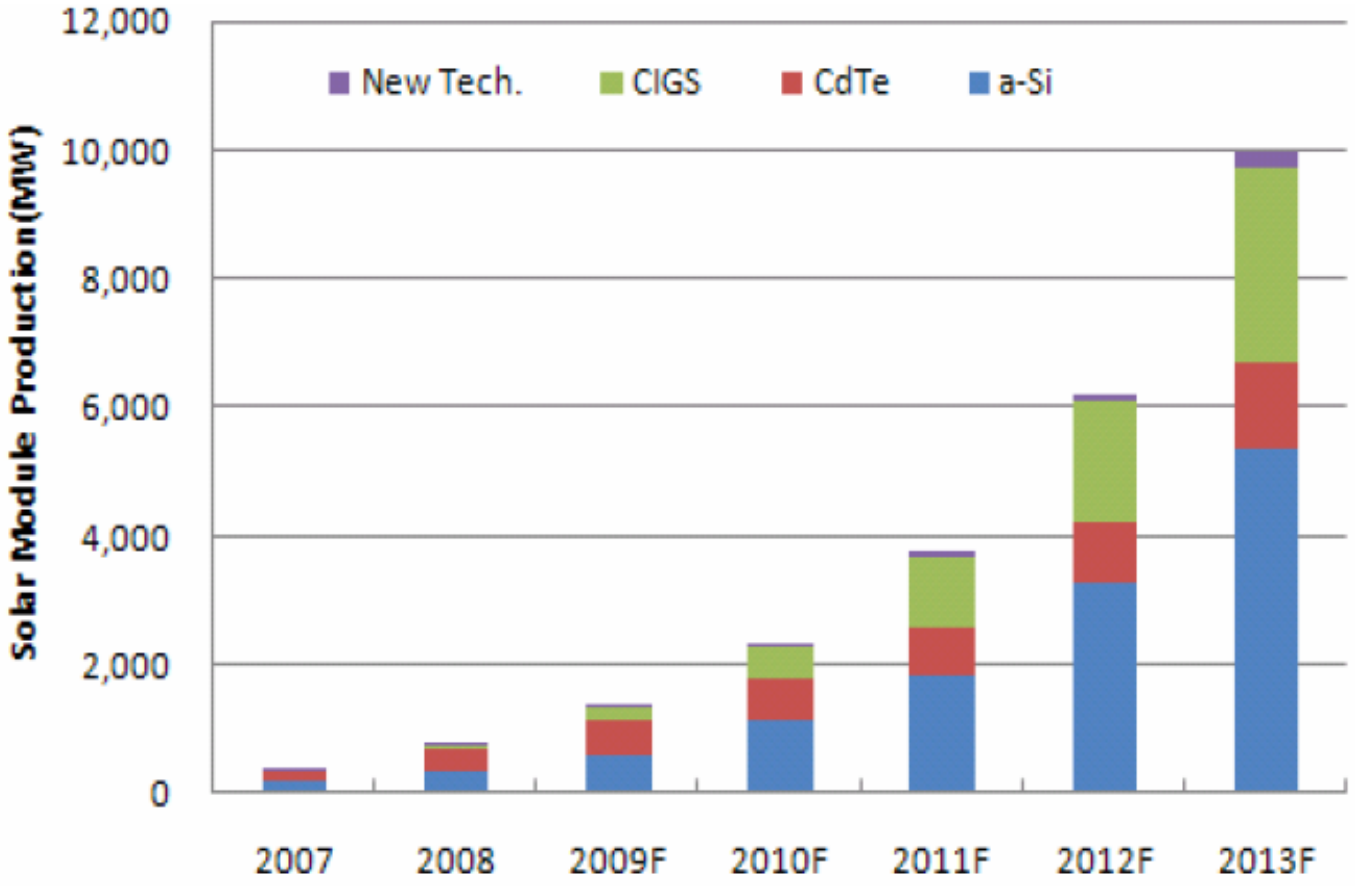
- Material unlimited
- Well developed technology
- Relative simple manufacturing process
- Can be used everywhere
- Off grid (small scale) to on grid (large scale) application

CIGS 薄膜太陽能電池

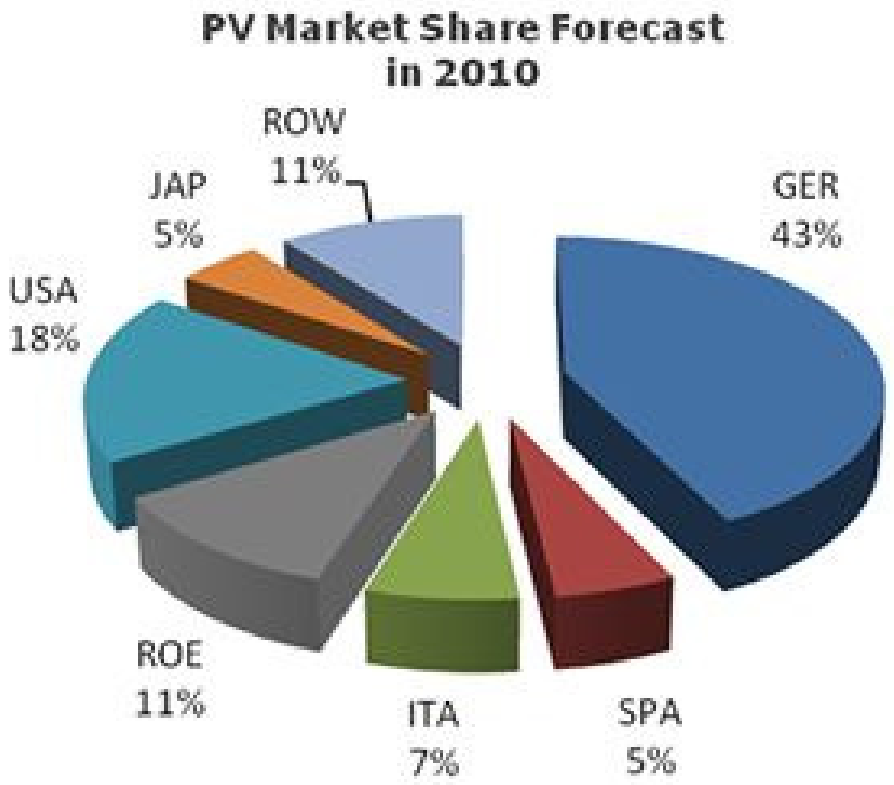
$Cu(InGa)Se_2$

- 在各類薄膜電池技術中，相對轉換效率高
- 在室外長期使用的穩定性已被證實
- 對高強度輻射的抵抗力優於矽晶電池
- 在弱光下的發電性能優於矽晶電池
- 重量輕(微米級)
- 可使用可撓性基板製作，用途廣泛

Global PV Module Production Forecast



2010 Global PV Market Share Forecast



Solarbuzz LLC: GREEN WORLD SCENARIO

Applications of CIGS PV Modules

Market	CIGS	Note
Solar Farms	✓	Need ~10% efficiency for large area installation 
Building Integrated PV (BIPV)	✓	Flexible substrate increases market opportunity 
Rooftop Grid Connected	✓	High efficiency required for small surface area 
Portable Devices	✓	Flexible substrate required 

Solar Farm

Solar Farm

Left: Solar PV power Plant Olivenza, Spain. Courtesy: SunPower Corp. Right: PV power plant Calvià , Mallorca, Spain. Courtesy: : MPC Capital Gruppe; MPC Capital AG
www.solarserver.de/solarmagazin/index-e.html

Solar Farm

Lucainena de las Torres PV power plant, Andalusia, Spain (Source: MEPSolar)
www.solarserver.de/solarmagazin/index-e.html

Rooftop

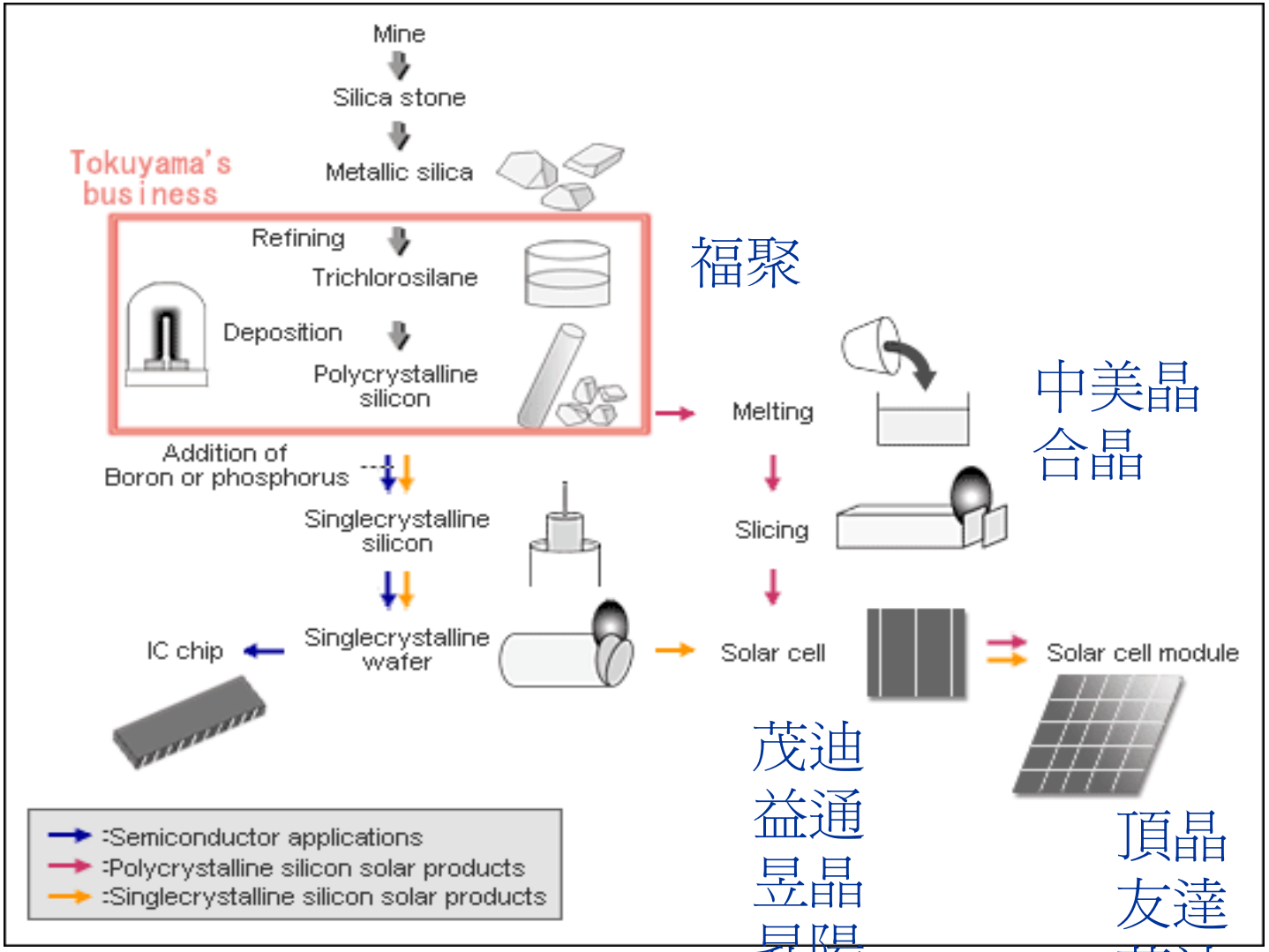
Rooftop

Source Sontor

Source: SIT

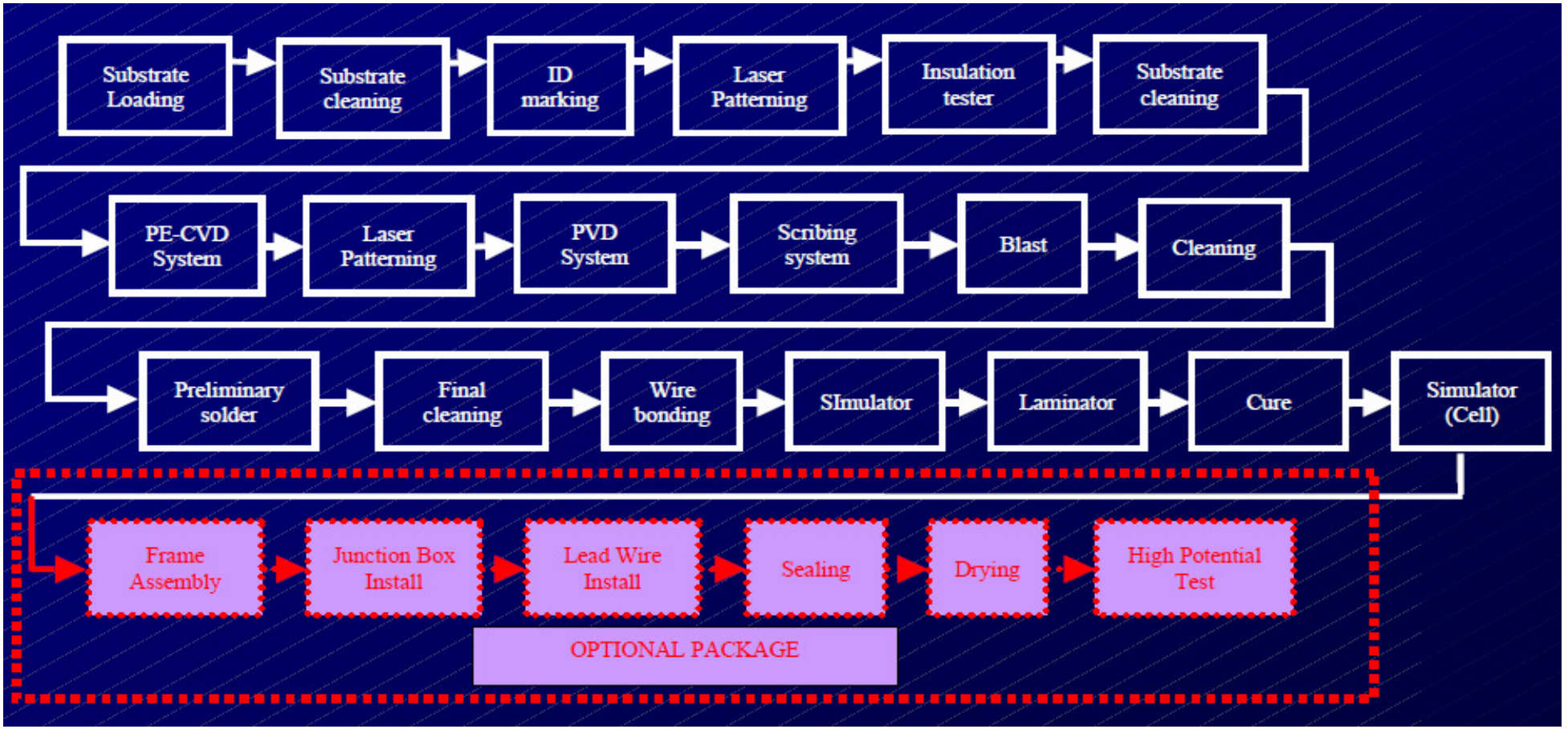
Consumable

Si-based Solar Cell/Module Manufacturing



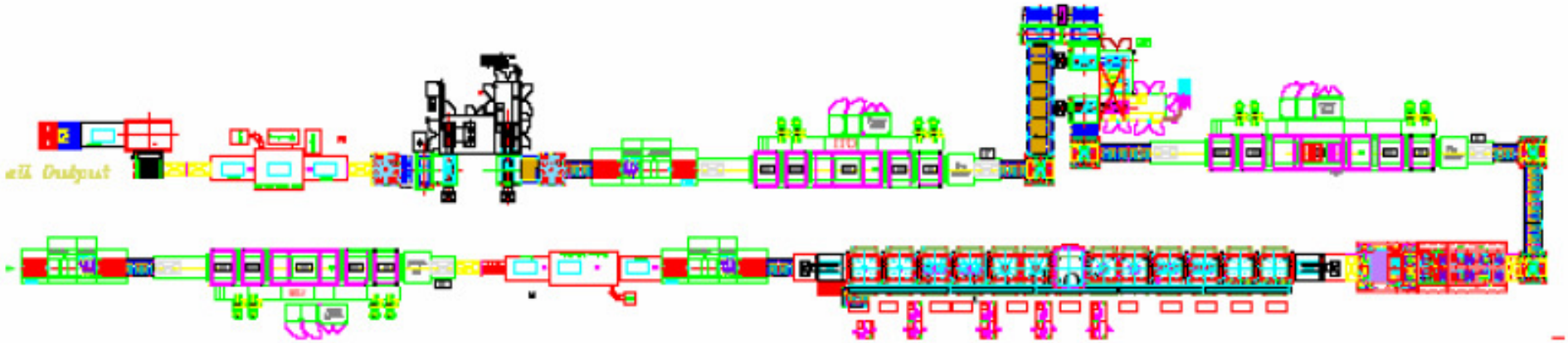
Source: Tokuyama's website

Amorphous-Si Thin Film Solar Cell Process Flow



Source: ULVAC Japan

CIGS Thin Film Solar Cell Process Flow



Glass Cleaner

PVD (Mo) Line

Laser Scriber

Glass Cleaner

CIGS Formation Line

CBD-CdS Coater

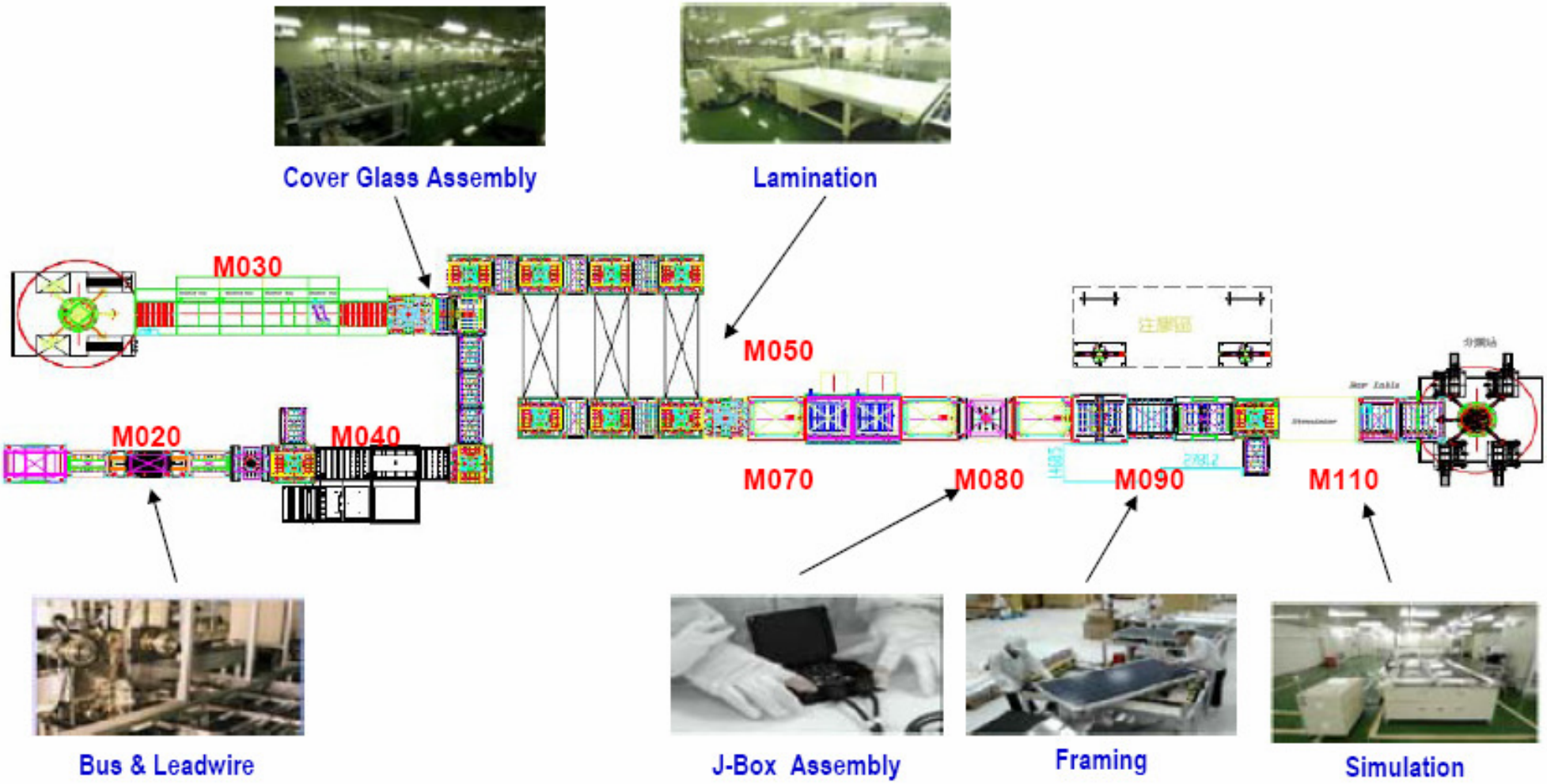
PVD (i-ZnO) Line

Machine Scriber

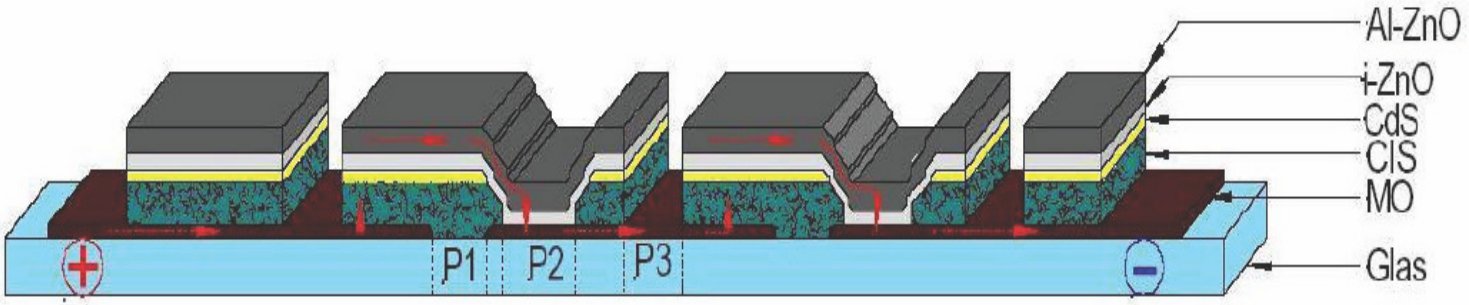
PVD (TCO) Line

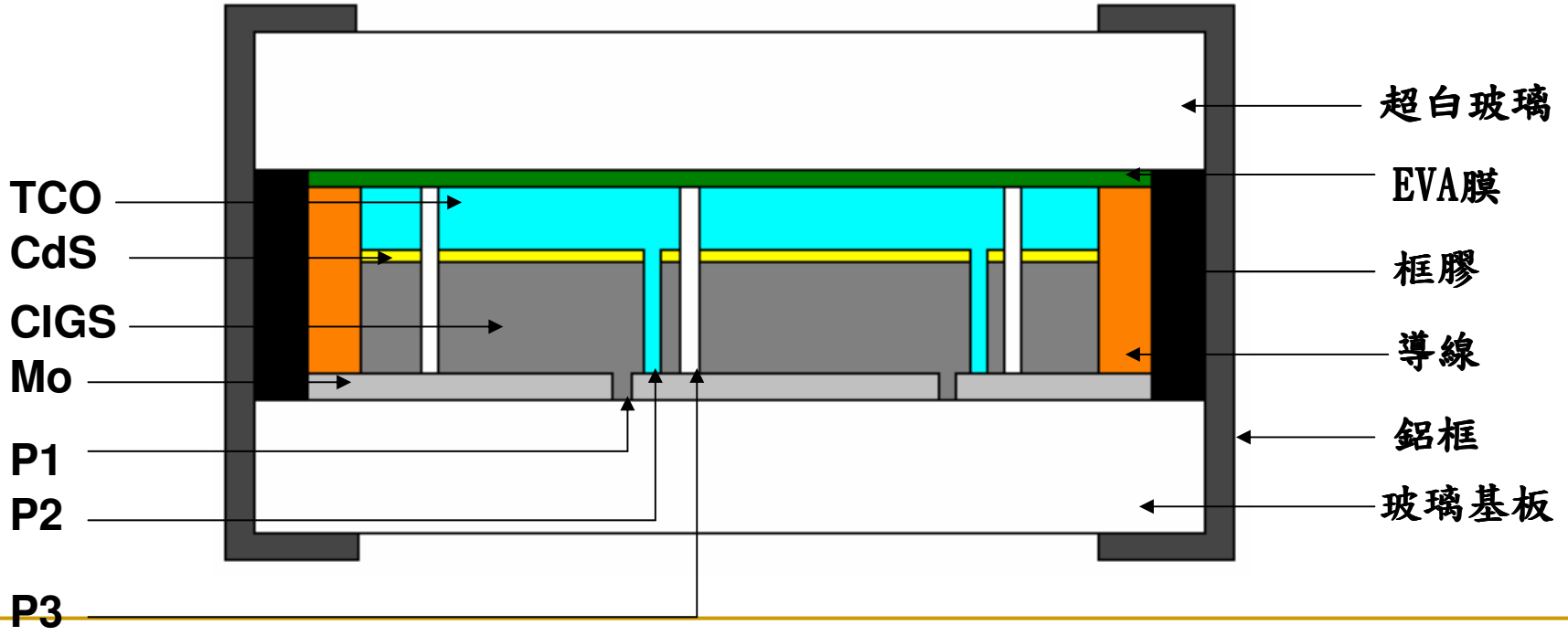
Machine Scriber

CIGS Thin Film PV Module Process Flow

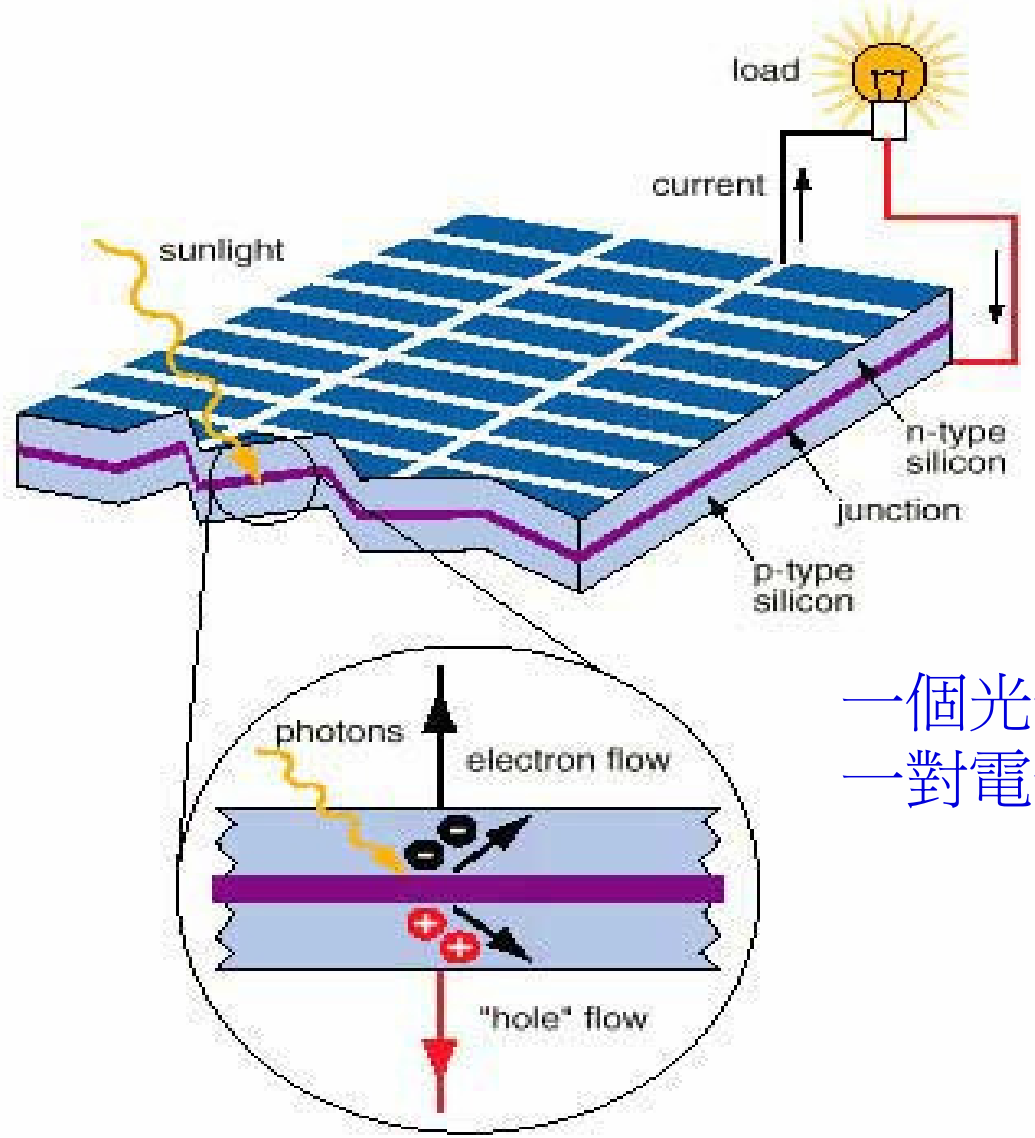


CIGS PV Cell/Module Cross Section



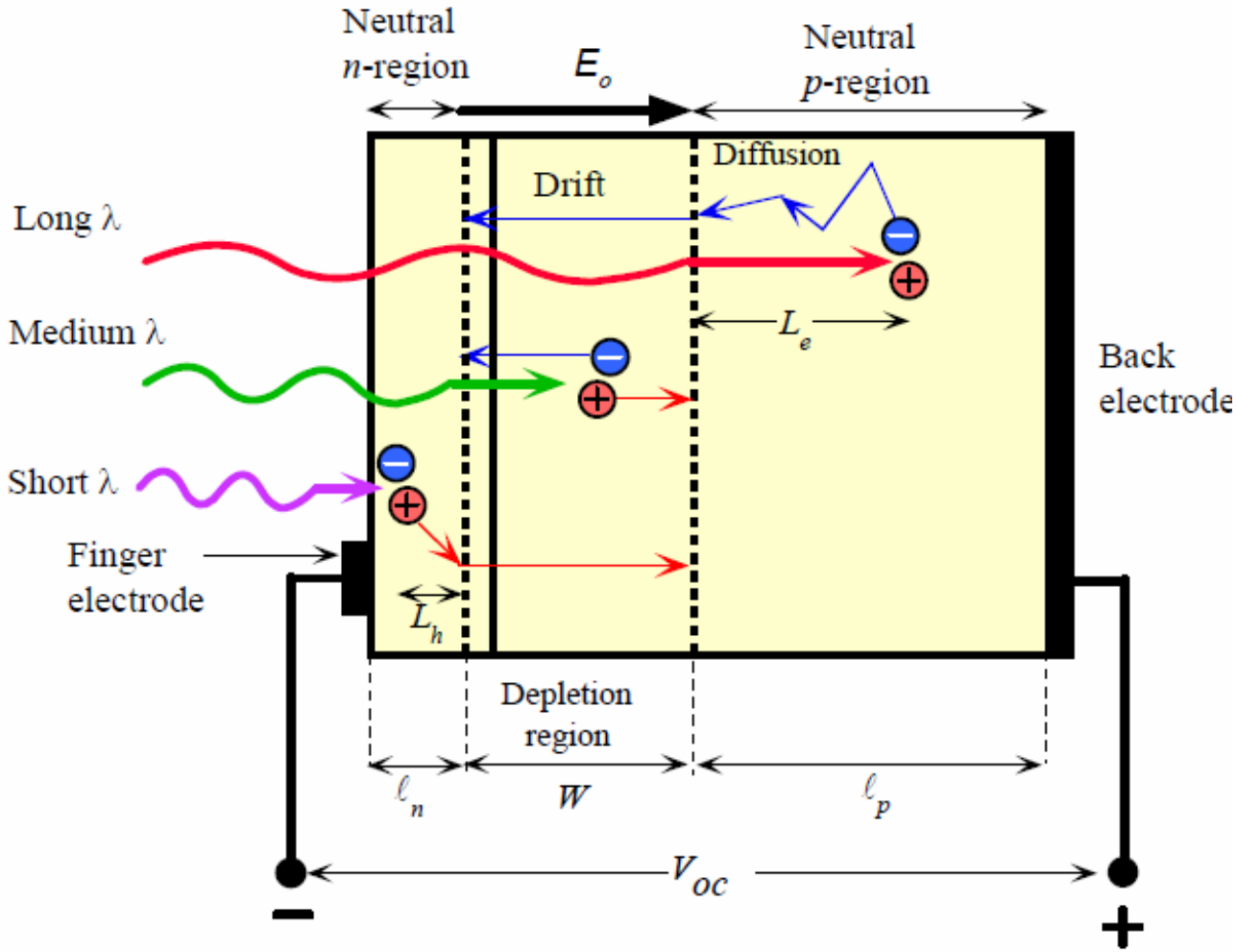


太陽能電池原理



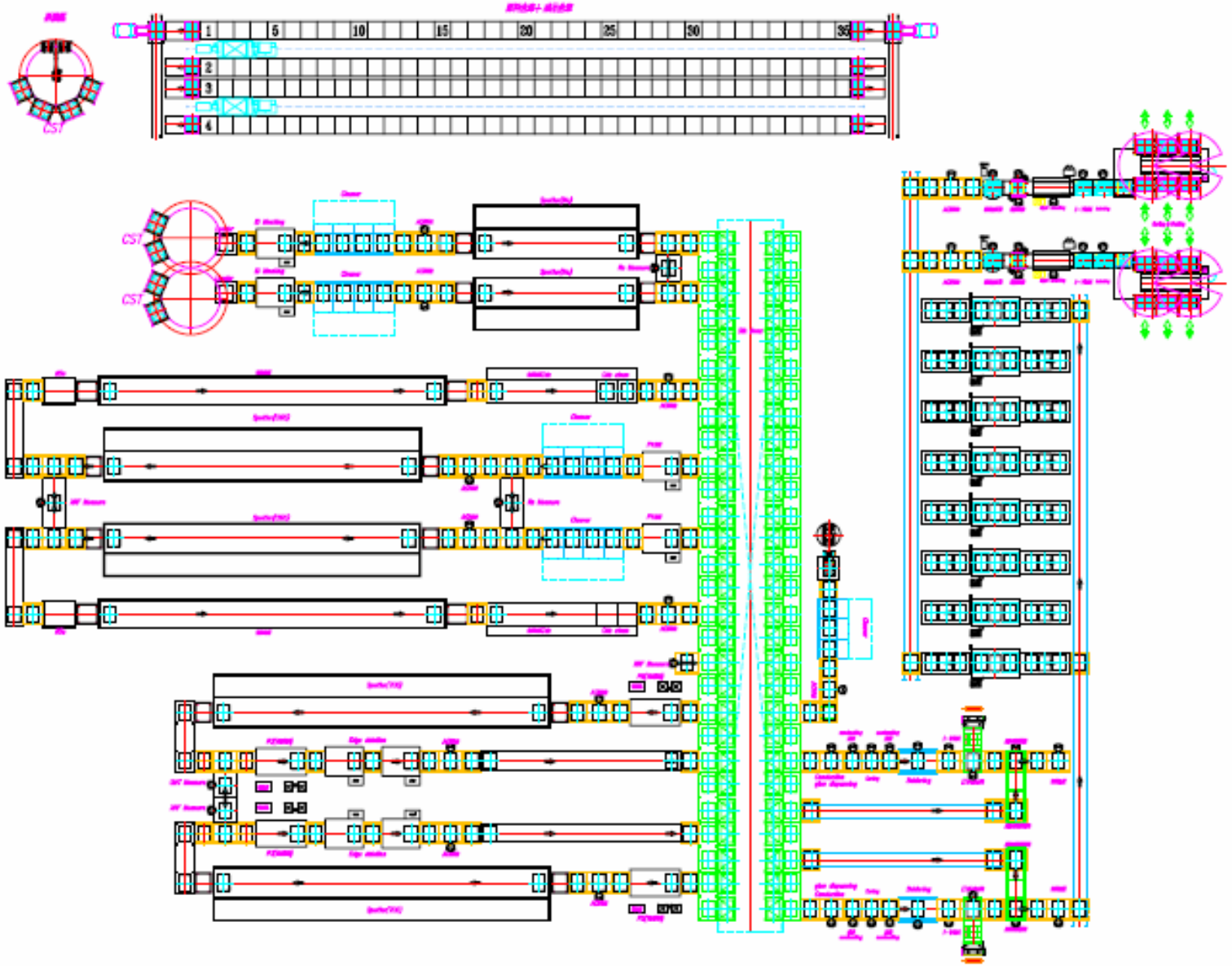
一個光子photon產生
一對電子-電動e-h pair

太陽能電池原理



長波長光照射 penetration depth 較深
有長波長吸收光譜

60MW (2x30 MW) CIGS Production Line Layout



In-line Metal Sputtering System

TCO Sputter

Laser Patterning

Selenization RTP Furnace

Laminator

CIGS PV Module Production Line

Our Project: a CIGS Line in Taiwan

Start Production: June, 2009

a-Si PV Module Production Line

Solar Cell and Module Power Output

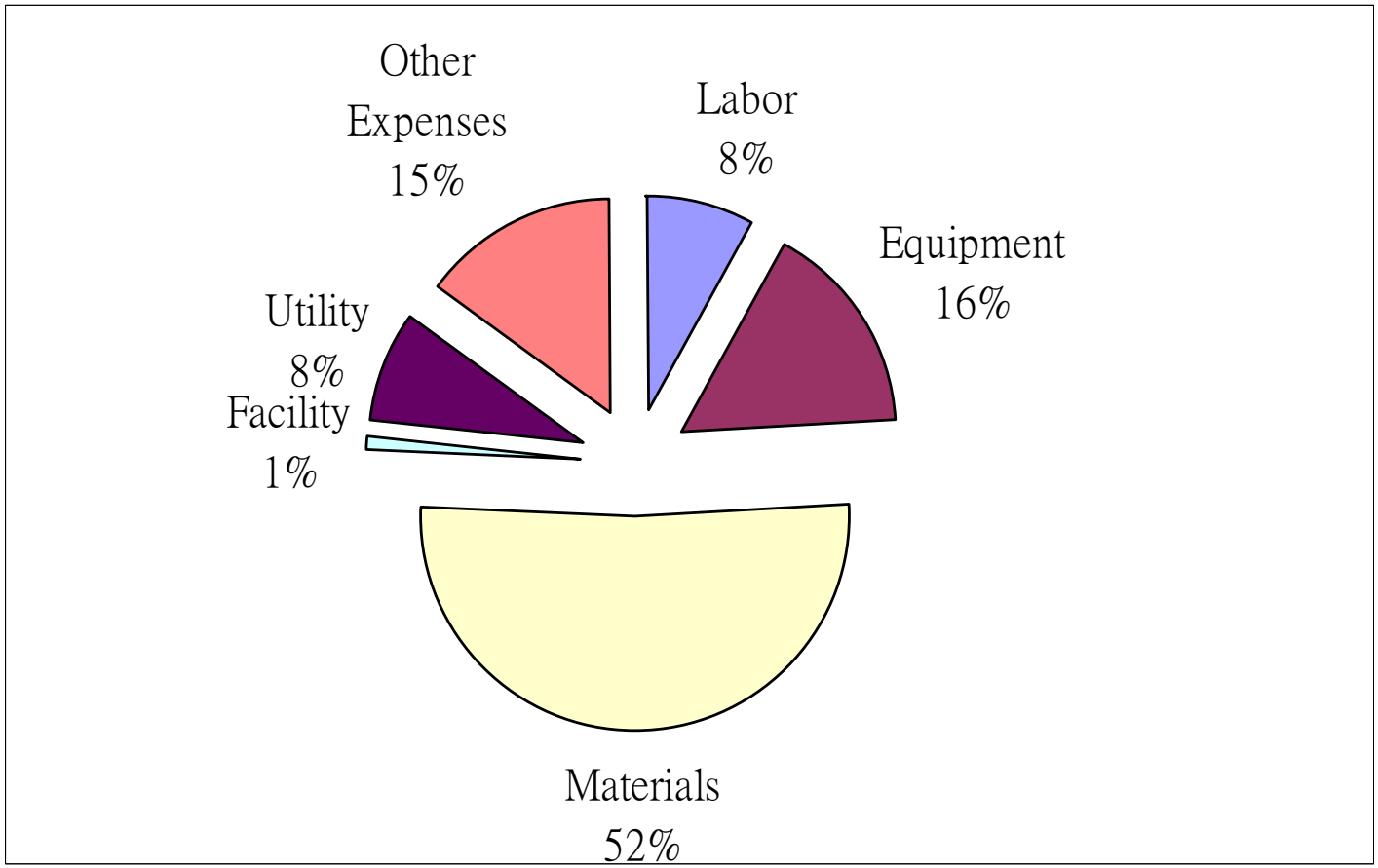
Standard Condition: AM 1.5, 1,000 W/m^2, 25℃

- if η =16% for 156mmx156mm (6吋) Si-based cell
  power : 15.6cmx15.6cmx0.1W/cm^2 x0.16=3.89 W

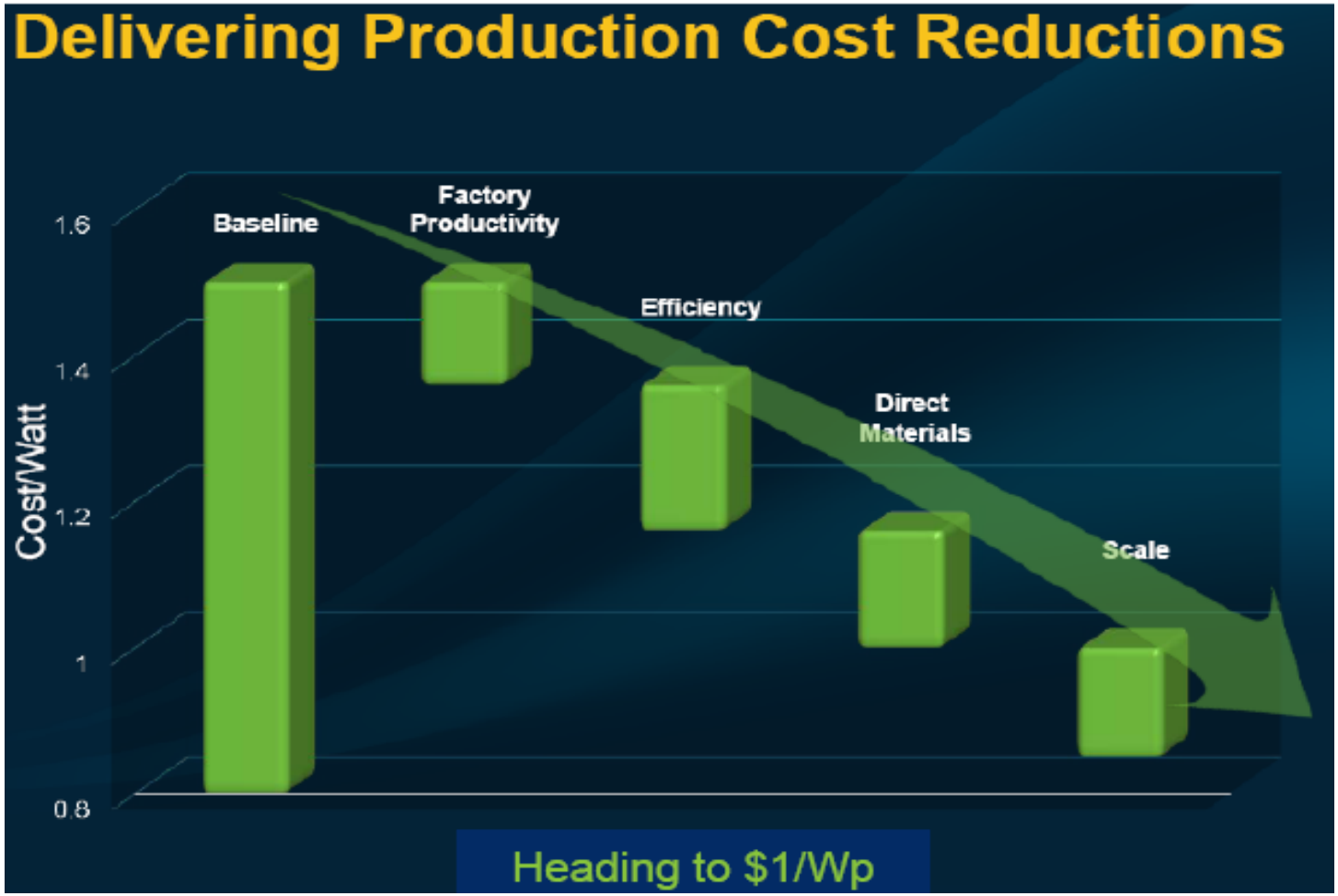
- 6x10 module
  power : 3.89 W x 6 x 10 = 233.4 W

Cost Structure for 30 MW CIGS Manufacturing

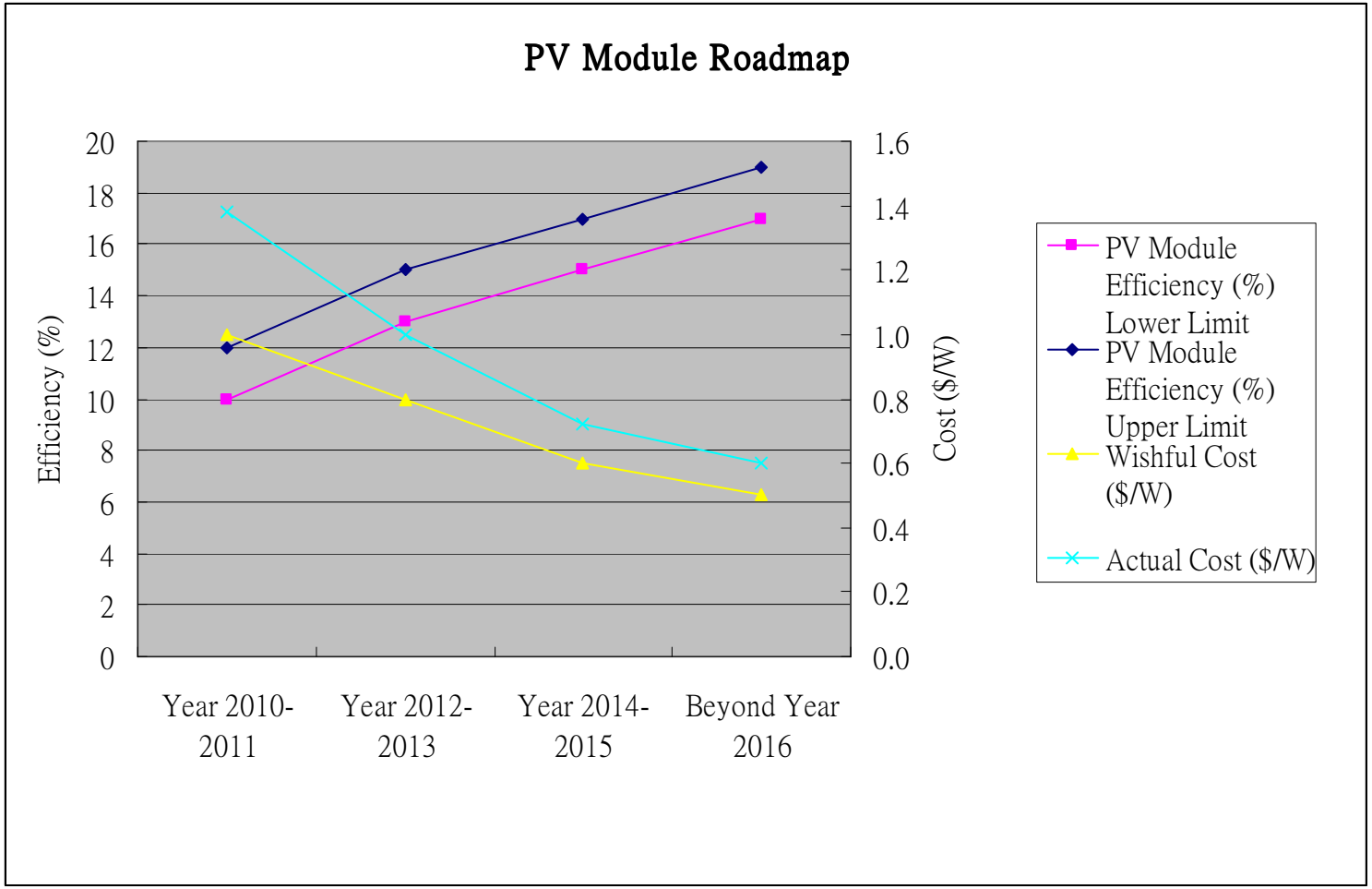
Standard: $1.379/W



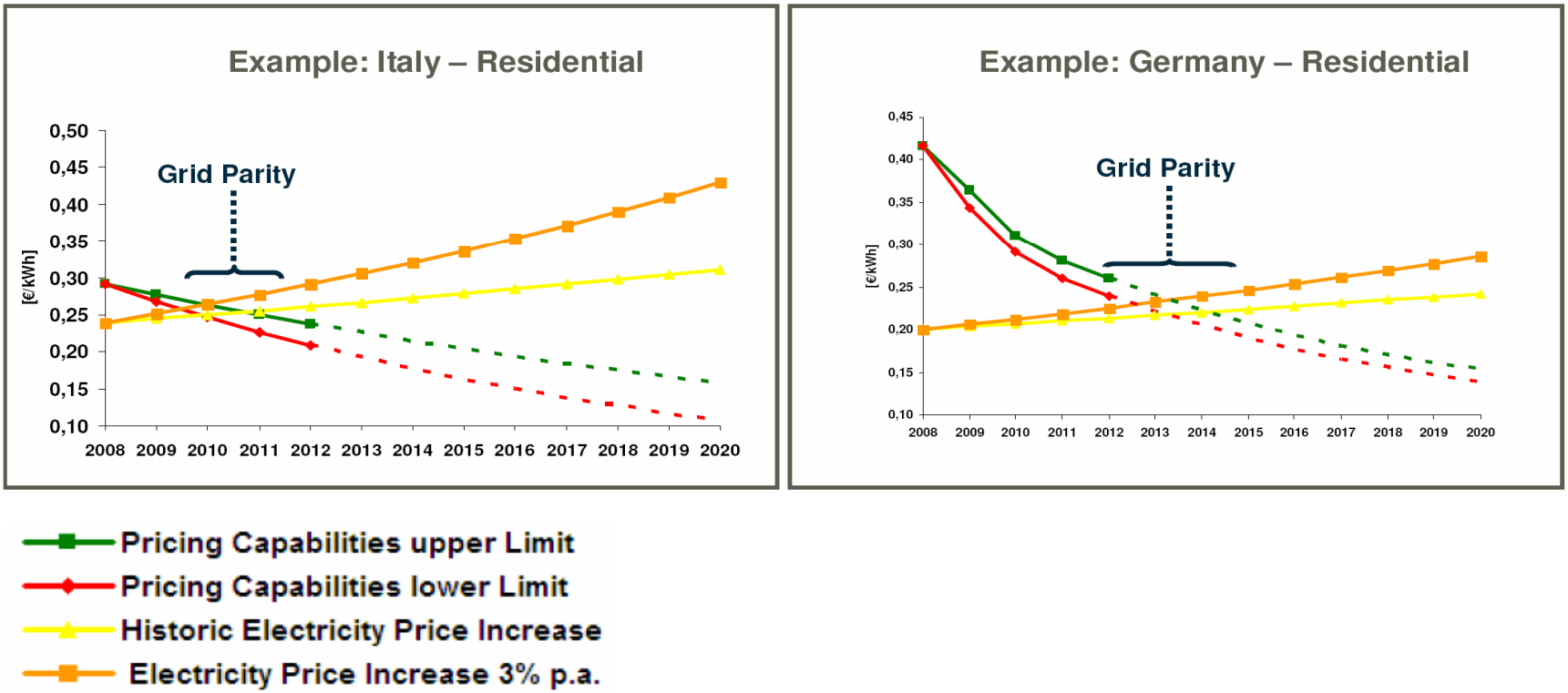
CIGS PV Module Production Cost



PV Module Production Roadmap



Grid Parity in Italy and Germany



Source: Q. Cells, Inter Solar May 2009, Germany

Revenue Forecast

年度	產能（百萬瓦）	售價（美元/瓦）	標準成本（美元/瓦）	營業額（新台幣百萬元）	總營業成本（新台幣百萬元）	營業損益（新台幣百萬元）
2010	0	1.65	2.00	-	-	-
2011	2	1.52	1.60	97	102	-5
2012	30	1.40	1.17	1,341	1,125	215
2013	60	1.28	1.03	2,467	1,980	486
2014	120	1.18	0.91	4,539	3,486	1,053
2015	220	1.09	0.80	7,656	5,623	2,032

Funding Requirement

Item	Fund (US$K)
Building/Clean Room/Facility	10,000
30 MW Demo Line	30,000
Inspection/Testing Equipment	580
Utility/Hook Up	4,310
Ramp Up: Labor	3,360
Ramp Up: Materials	2,430
Operations/Others	12,320
Total	**63,000**

Thank you for your attention