From Silicon to Solar Kilowatt-hour, BP Solar Path to Grid-Parity

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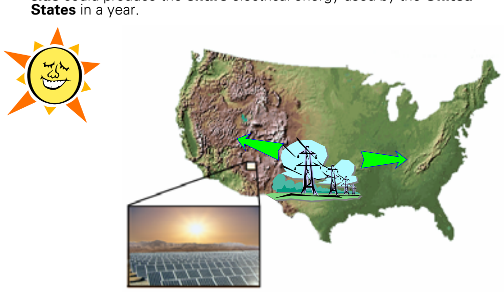
PV Background - Technology Overview

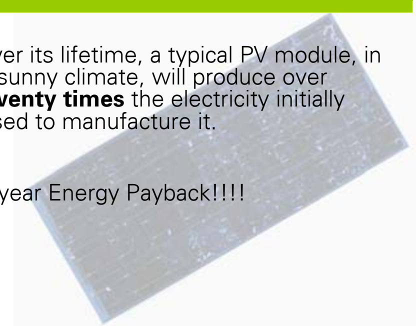
- **1839** Photovoltaic effect discovered by Edmond Becquerel
- **1921** The Nobel Prize in Physics is awarded to Albert Einstein "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect"
- **1954** First silicon p/n junction solar cell made at Bell Labs
- **1958** Solar cells used to power satellites (Vanguard I)
- **1973** Solarex established, spin-off of Comsat Labs (J.L Lindmeyer, P.Varadi)
- **1979** Invention of Solarex poly-crystalline silicon process
- **1980** BP enters solar industry via purchase of Lucas Energy Systems
- **1985** BP Solar acquires license for Laser Grooved Buried Grid Process
- **1997** Solarex (then 50% owned by ENRON) started production of amorphous silicon modules
- **1999** BP and Amoco merge (ENRON bought out), BP Solarex formed
- **2000** BP Solar consolidated

PV Facts

Using today's PV Technology, an array field that is **300 miles on each side** could produce the **entire** electrical energy used by the **United States** in a year.



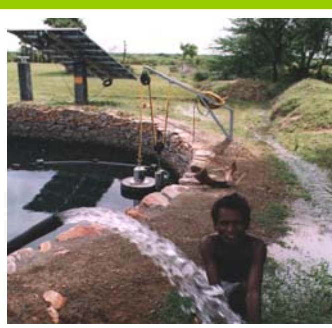
PV Facts



Over its lifetime, a typical PV module, in a sunny climate, will produce over **twenty times** the electricity initially used to manufacture it.

2-year Energy Payback!!!!

Remote Application: Water Pumping



Remote Application: Education

BP Solar modules provide electricity to 1,852 schools in Brazil: lights, TV/Satellite/video and refrigerator.

Remote Application: Health Clinics

Lighting, Philippines

Vaccine Refrigerator, Ethiopia

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Remote Application: Village Power

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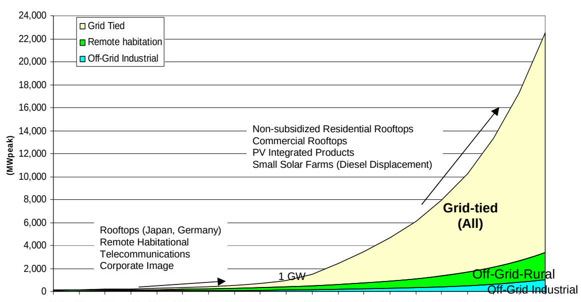
PV Market: Growth Expectations



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Residential Retrofit

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Residential Retrofit

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Roof Integration: EnergyTile™

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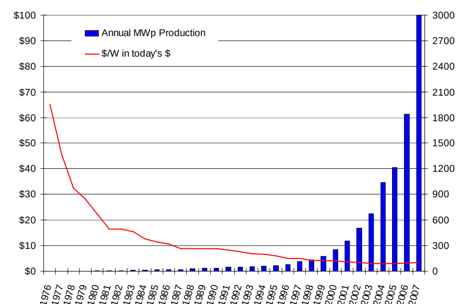
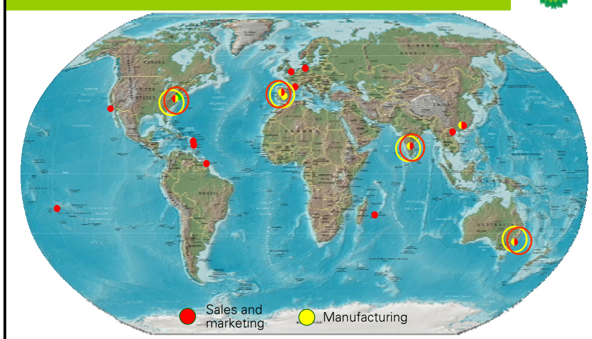
Residential Roof Application

Commercial Application

Historical Average Selling Price and Volume



BP Solar Global Presence



Solar PV Value Chain

Metallurgical Silicon → **Semi-conductor Silicon** → **Crystal Growth** → **Wafering** → **Cell Fabrication** → **Module Assembly** → **System & Channel**

- Quartz to MG Si
  - MG Si to Solar grade Si
    - MG Si to ingots
      - Ingots to wafers
        - Wafers to solar cells
          - Cells to modules
            - Modules to installed systems

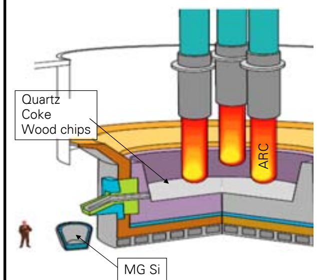
Silicon basics

Relative Abundance

ELEMENT	Weight % of Earth's Crust
Arsenic	*0.0001800%*
Cadmium	*0.0000200%*
Copper	0.0015000%
Gallium	*0.0055000%*
Indium	*0.0000100%*
Gold	0.0000004%
Oxygen	**46.100000%**
Phosphorus	0.1050000%
Selenium	*0.0000050%*
Silicon	**28.2000000%**
Silver	0.0000070%
Sulfur	*0.0260000%*
Tellurium	*0.0000001%*

Silicon in use everyday

Metallurgical refining

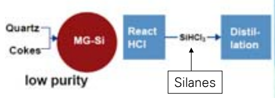


Source: ECN Sept. 2005, BP Solar

Industrial production of metallurgical-Si (since 1905)

Silane distillation for higher purity Si

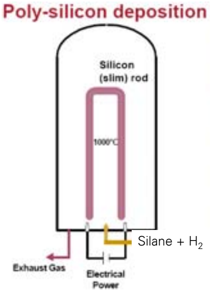
From quartz to high purity silanes

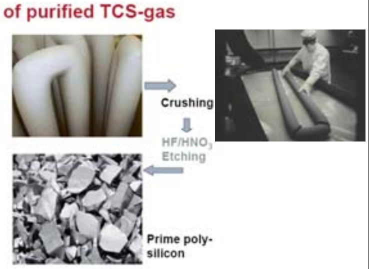


Source: ECN Sept. 2005

Pure Silicon Deposition (Siemens Process)

Poly-silicon deposition of purified TCS-gas





Source: Wacker 2nd SoG-Si Workshop

Source: ECN Sept. 2005

BP Solar Multi-crystalline Process

Silicon "nuggets"

In the cast process, silicon pieces are molten in a ceramic crucible to form an ingot that in turn is cut into smaller "bricks".

Silicon Cast Ingot

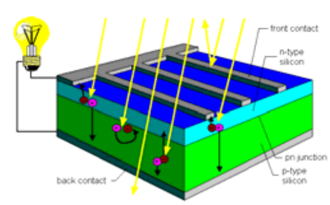
Multi "bricks"

Multi Wafer

Multi Cell

Solar Cell Device: How it Works?

- A photon is absorbed in the active part of the material resulting in electrons being exited to a higher energy potential
- The charge carriers created by photon absorption are physically separated and moved to each side of the cell
- The charge carriers are removed from the cell and delivered to an external load where they perform useful work (pump, light etc…)



Screen-Printed Cell

BP Solar Module Types

Multi-crystalline Module

Mono-crystalline Laser-Grooved (Saturn)

Mono-crystalline Screen-print

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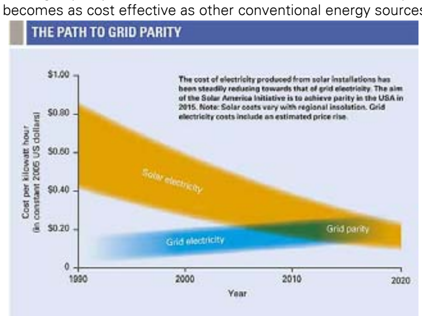
Primary technology objective/mandate

Drive PV $/kWh to grid-parity for residential and commercial markets (the point at which solar energy becomes as cost effective as other conventional energy sources)



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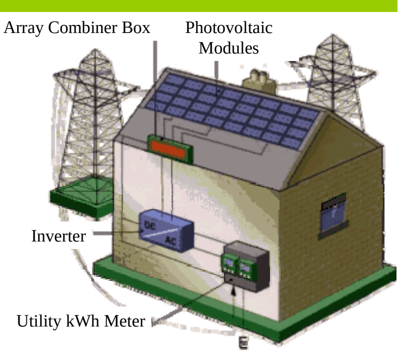
Residential System



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PV kWh costs in different zones

Location	Residential Retail (US ¢/kWh)	PV retail amortized cost (before rebate)	Residential PV Rebates
PG&E (Northern CA)	35 ¢/kWh (noon to 6 PM)	~20 ¢/kWh	One time rebate ($2.20/W in 2007)
Hawaii	24 ¢/kWh	~18 ¢/kWh	30%
Tokyo (Japan)	23 ¢/kWh	~23 ¢/kWh	Almost gone
Italy	21 ¢/kWh	~20 ¢/kWh	Suggested 60 ¢/kWh
Spain	24 ¢/kWh	~20 ¢/kWh	~70 ¢/kWh
Germany	25 - 30 ¢/kWh	~45 ¢/kWh	Up to 85 ¢/kWh
LADWP (Los Angeles CA)	14 ¢/kWh	~20 ¢/kWh	One time rebate
France	24 ¢/kWh	~25 ¢/kWh (South)	Up to 85¢/kWh

Notes:
- We are at parity in some areas. Grid costs continue to rise, environmental costs under consideration and peak kWh costs can reach up to $1.50 per kWh or more during peak-time periods
- Assumes today's residential system cost of ~$8.00/W installed
- Green shaded cells are locations where grid-parity is already a reality

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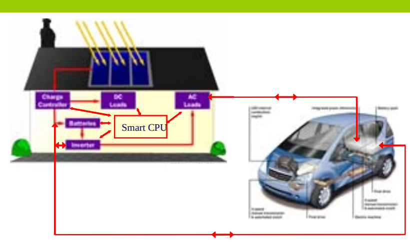
Zero+ Energy Family Home



- Today, a 30 mpg conventional car costs 13 ¢ per mile in the US (20 to 25 ¢ in Europe) for fuel only.
- Similarly, an electric car costs 4 to 5 ¢ per mile when re-charged from the grid or 10 to 15 ¢ from PV electricity
- More advances in storage technologies needed to allow for more electric and extended hybrids to have a larger impact. Natural choice for Europe in the near term.

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Conclusions

- Grid-parity within reach (2010 and beyond)
- Silicon base element for the next few years
- Tremendous growth
- Reduce carbon foot-print
- National grid support

Thank you for your attention!

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