Energy Harvesting for Portable Devices: Solar Energy for Cell Phones

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Introduction

- Estimated 6 billion cell phone users in the world in 2011 (ITU World Telecommunication/ICT Indicators database)
- 76% of total cell phone users live in developing countries

Current Problem:

- Cell phones require frequent charging, making them less autonomous
- Many users in developing countries do not have access to grid electricity or charging stations are miles from villages

Solution:

Portable energy harvester to power mobile phones using photovoltaics

Energy Requirement of a Cell Phone

Total load requirement of a cell phone :

Cell Phone Activity	Hours/day	Power Consumpion (W)	Daily Energy Consumption (Wh/day)
Phone Call	1	1	1
Standby	18	0.01	0.2
Idle	5	0.5	2.5
Total	**24**	-	**3.7**

Source: A. Rice et al. Measuring mobile phone energy consumption for 802.11 wireless networking. *Pervasive and Mobile Computing*, vol. 6, pp. 593-606, (2010).

- Examined three regions of similar lattitude with high solar radiance
  - Average 6 hours of sunlight at an insolation of 100mW/cm^2
- For a 6 hour charge time, power required is:

$$Required\ Power = \frac{Daily\ Energy\ Consumption}{Total\ Charge\ Time\ per\ Day} = \frac{3.7}{6}\frac{Wh/Day}{h/Day} \sim 0.6\ Watts$$

Can we use solar energy for cell phones?

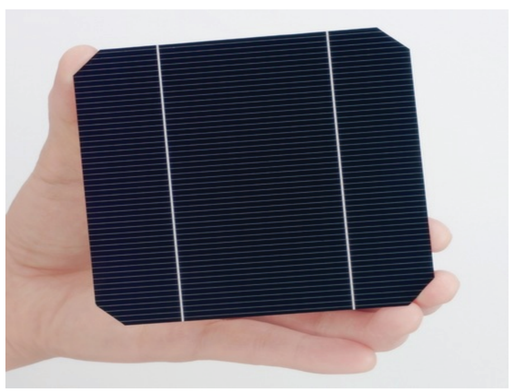
Monocrystalline Silicon cells offer the best available photovoltaic (PV) solution based on high conversion efficiency of about 20%

- Cells made from a thin slice of a large single crystal of pure molten silicon
- Extremely brittle and fragile so an effective packaging method is necessary to allow monocrystalline silicon cells to be portable

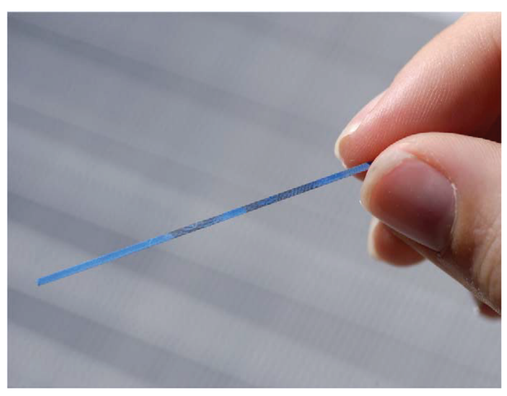
Two options were examined:

- Encapsulate and embed **conventional cells** in a protective frame, or
- Slice cells to very small thicknesses to create **flexible cells**

	Conventional	Flexible
Efficiency, η	≈20%	19.6%
Open Circuit Voltage, V_{OC}	676 mV	686 mV
Short Circuit Current Density, J_{SC}	39.3 mA/cm^2	37.1mA/cm^2
Area	4 cm^2	1 cm^2
Power/cell	77.6 mW	19.6 mW



Source: pvsolarchina.com/5-monocrystalline-silicon-5-inch-125-series-solar-cell.html



Source: P. Verlinden, et. al. Sliver solar cells: A New Thin-Crystalline Silicon Photovoltaic Technology. *Solar Energy Materials and Solar Cells*, 9:3426, 2006.

Required Power	0.6 W
Required Power (considering current losses and other maintenance losses, η = 0.83)	0.72 W
Required Power (considering conservative design, η = 0.5)	**1.4 W**
Panel Area Required for 20% efficient Cells	**70 cm^2**

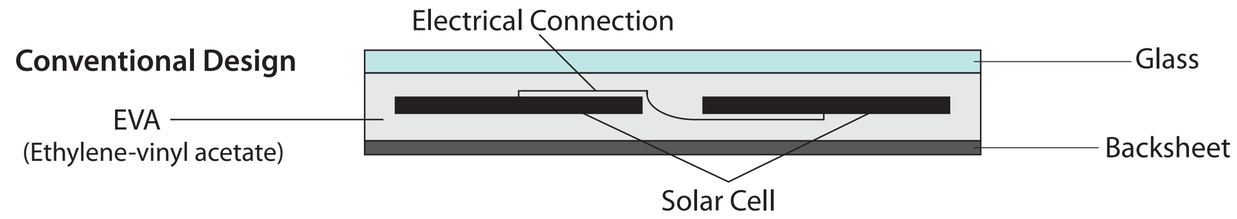
A look at Required Panel Size vs. Typical Phone Size

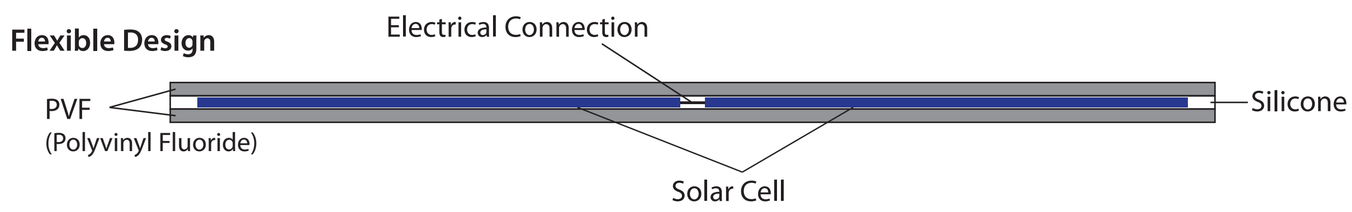
Surface Area of an iPhone 67 cm^2

Proposed panel size 70 cm^2

Panel Design: Conventional vs. Flexible

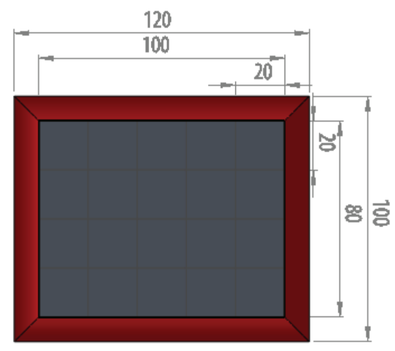
	Conventional	Flexible
Panel Area	80 cm^2	80 cm^2
Total number of cells	20	80
Cells in Series	10	10
Arrays in Parallel	2	8
Module Voltage	4.9 V	5.3 V
Module Current	314.4 mA	296.8.mA
Module Rated power	**1.55 W**	**1.57 W**





Mechanical Properties

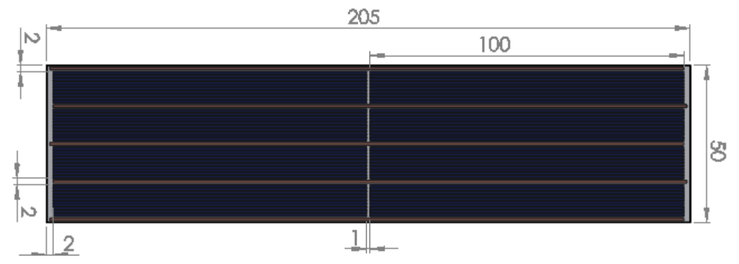
Conventional



- Cell thickness: 200 µm
- Module Weight: 100 g
- Susceptible to brittle fracture
- Must be kept flat and rigid to avoid fracture

*Dimensions in mm

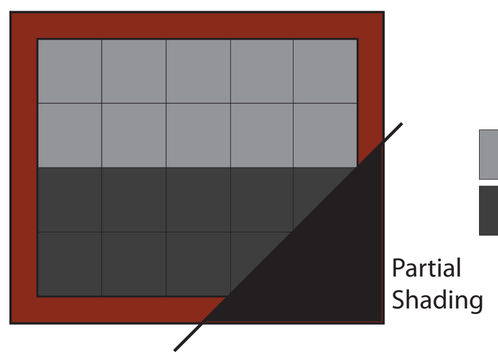
Flexible



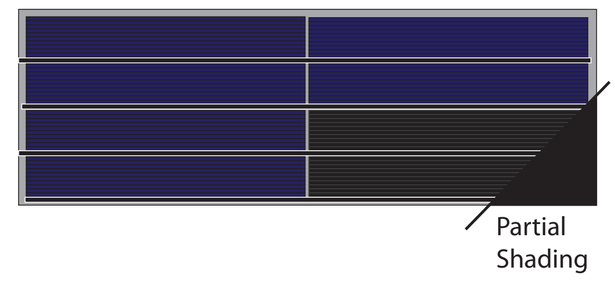
- Cell thickness: 50 µm
- Module Weight: 5 g
- Can undergo considerable deformation before fracture

Electrical Connection

- Electrical contacts placed on top of cells create shadowing losses
- Series connected modules respond poorly to partial shading



- Electrical connections made on the side of each cell so no losses due to shading
- Redundant parallel connections provide improved response to partial shading



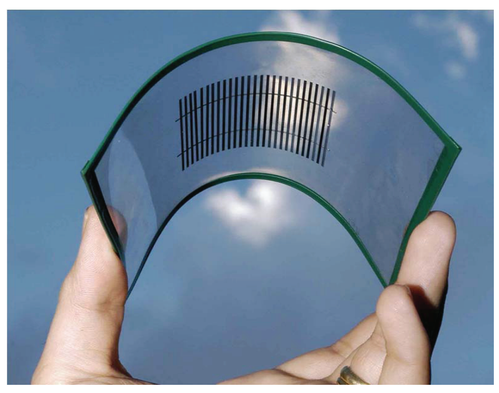
Advantages and Applications of Flexible Cells

Advantages

- Conform to complex geometry due to small cell size
- Easily obtain voltage of 5V required for charging USB devices such as cell phones
- Can withstand one time and repeated flexure

Applications

- Possible to integrate into apparel such as clothing or backpacks or onto the back panel of electronics
- Rollable panels can allow storage of large modules in small, portable cases



Source: Evan Franklin et. al. Sliver Solar Cells: High-Efficiency, Low-Cost PV Technology. *Advances in OptoElectronics*.Vol 2007: 3.

Conclusions

- Solar energy can be used in stand-alone systems to power cell phones or act as a supplemental source to avoid the need for frequent charging
- Monocrystalline solar cells offer the best solution due to its high efficiency
- Power requirements can be met with a 70 cm^2 solar panel under optimal conditions
- Different design options exist for monocrystalline cells: conventional and flexible

Flexible solar cells:

- Have better mechanical stability and electrical reliability than conventional crystalline silicon cells while still maintaining high efficiencies
- Potential for diverse applications such as apparel integrated photovoltaics or direct application onto portable electronics