



SOLAR DECATHLON 2009

Electronics

The Other Silicon in Solar



National Renewable
Energy Laboratory
Innovation for Our Energy Future



Your life. Plugged in.™



Periodic Table																Periodic Table													
1	Periodic Table																2												
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Periodic Table																Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Paul Westbrook
Sustainable Development Manager





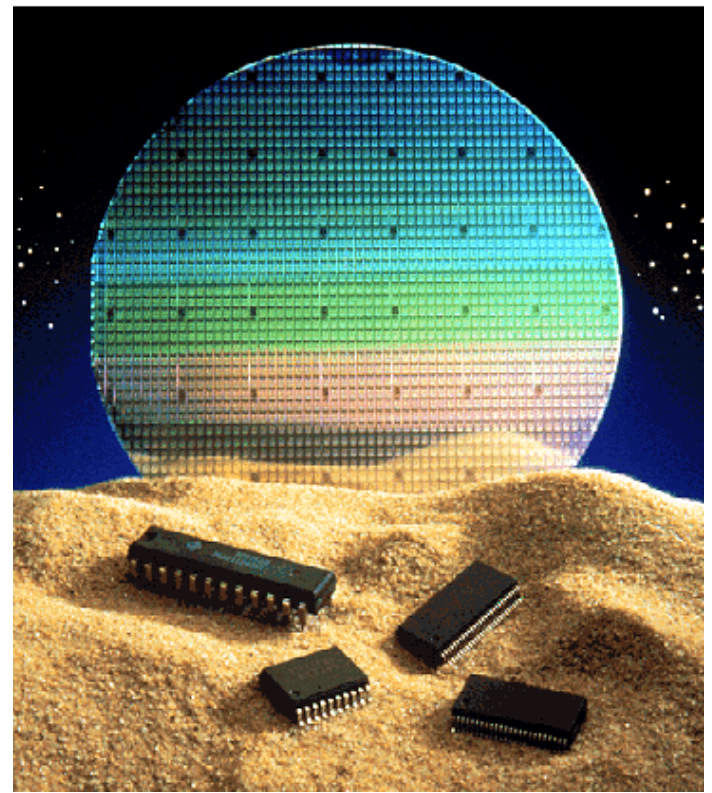
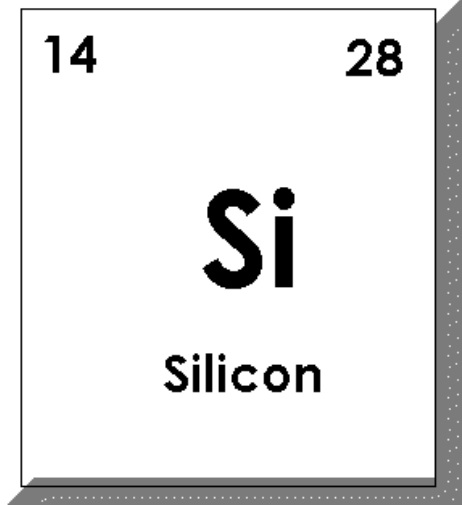
Outline

- Silicon in Solar and Electronics
- **Make It** – Energy Production
- **Move It** – Energy Transmission
- **Use It** – Energy Efficiency
- Integrated Design



Silicon Based Industries

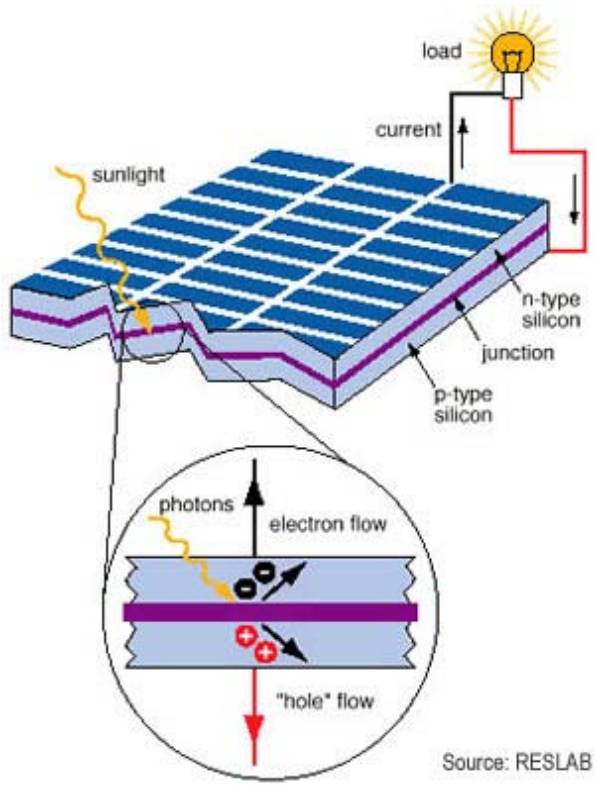
- Two silicon based industries:
- Photovoltaics (PV) and Semiconductor Manufacturing



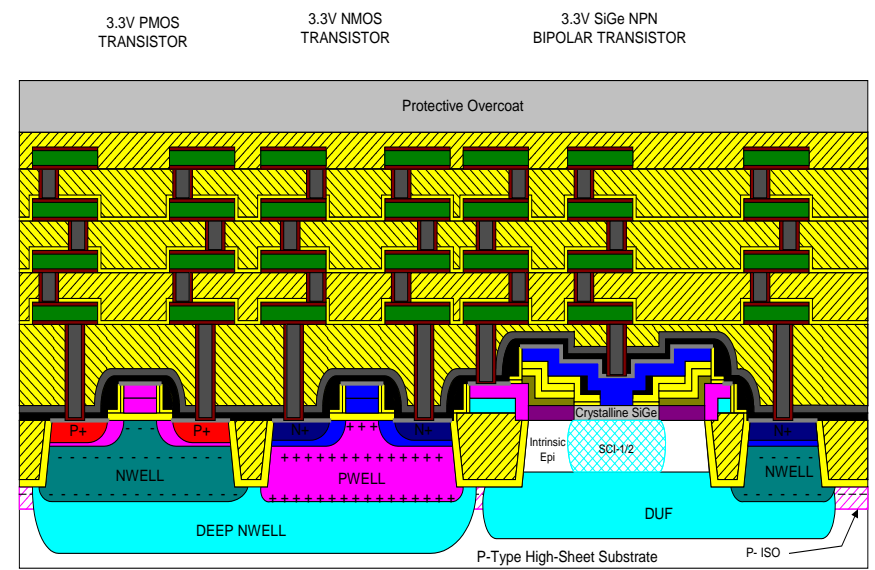
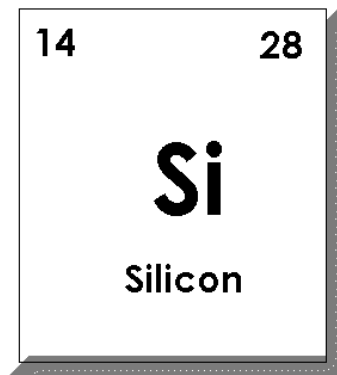


Silicon Based Industries

- Varying levels of complexity:
- Photovoltaics (PV) and Semiconductor Manufacturing



Source: RESLAB



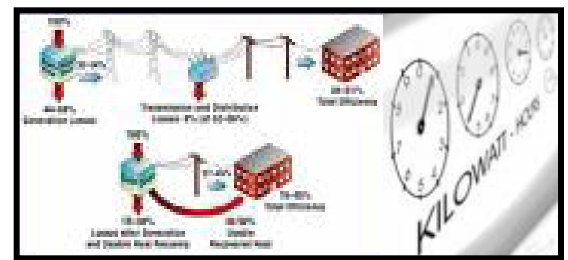


Energy - Make It, Move It, Use It



Energy Sources

- **Conventional Energy**
(Coal, Oil, Natural Gas, Nuclear, etc...)
- **Renewable Energy**
(Solar, Wind, Hydro, Tidal, Fuel Cell, Geo-Thermal, etc...)
- **Energy Harvesting**
(Kinetic, Vibration, etc...)



Transmission & Distribution

- Metering & Smart Grid
- Automated Metering Infrastructure
 - Powerline Communications
 - Time of Use Billing
 - Broadband
- Monitoring & Management



Consumption & Usage

- Energy Efficiency Appliances
- HVAC
- Lighting
- Transportation
- Electronics
- Industrial
- Waste
- Water



Make It

Move It

Use It



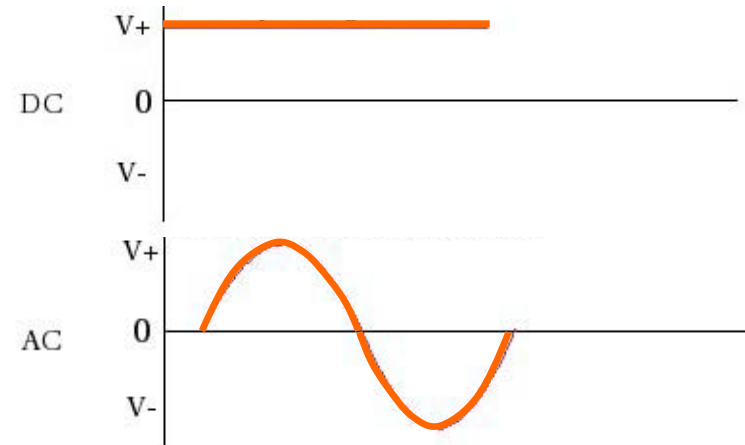
PV (DC) to Grid (AC)



Thomas Edison – DC proponent

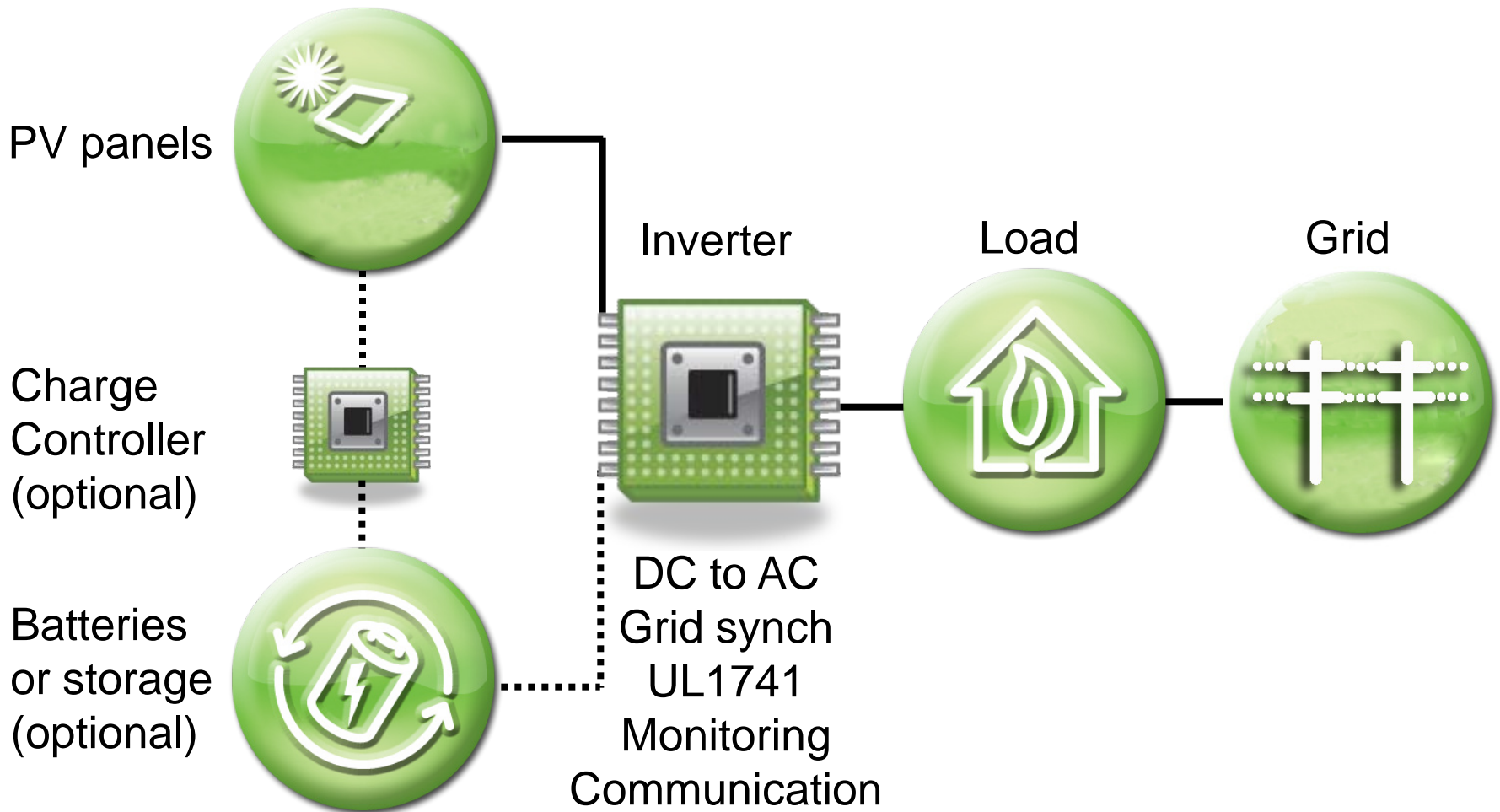
Nikola Tesla – AC proponent

- Direct current (DC)
 - PV panels produce DC
 - Batteries also use DC
- Alternating current (AC)
 - Most transmission and use is AC
- Inverters are devices that convert DC to AC and synchronize with the power grid (at 60Hz)



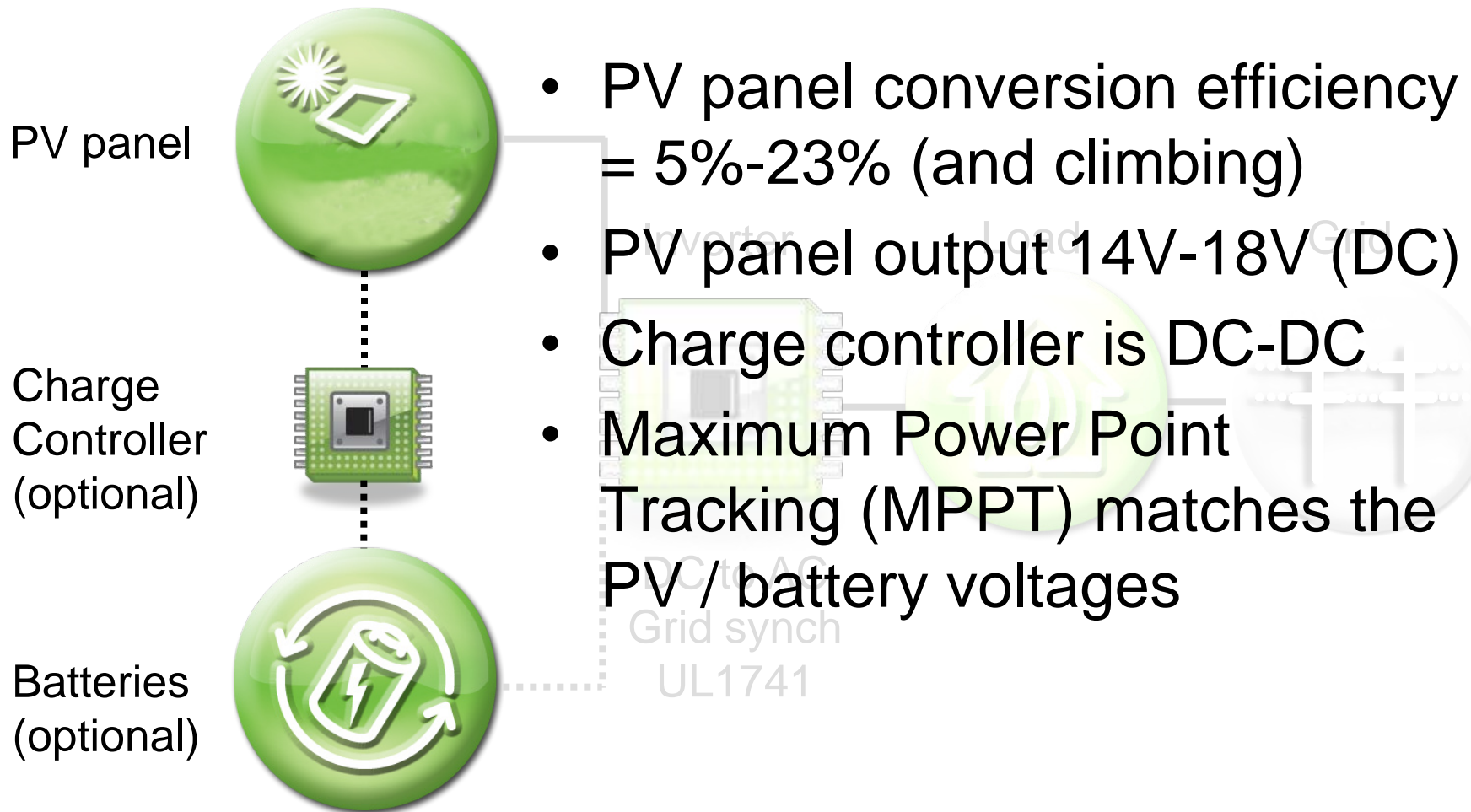


Make It - Power Production



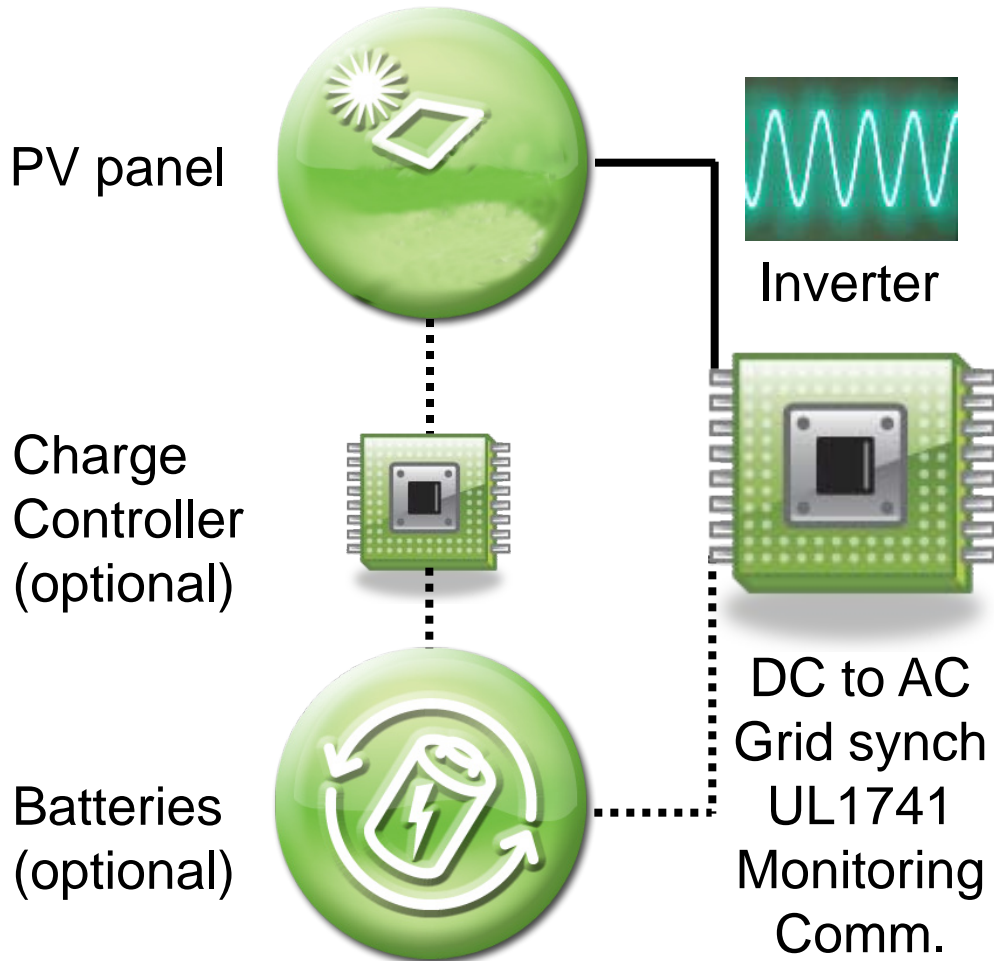


Charge Controller





Inverter

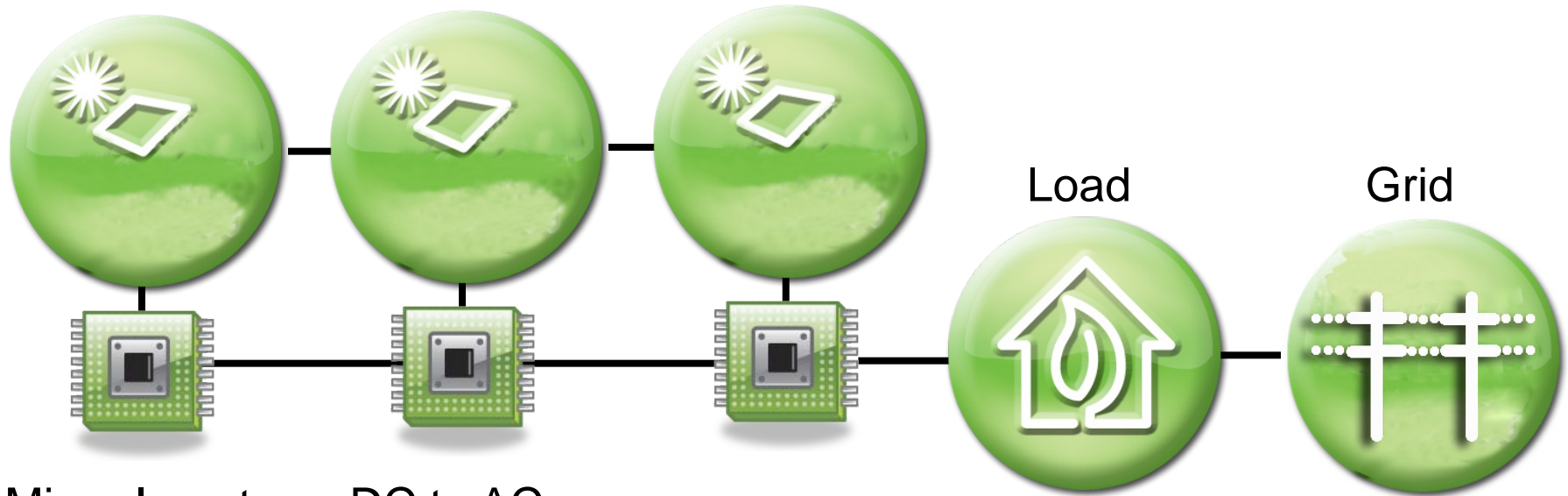


- Inverter efficiency 85%-98%
- Grid 60Hz synchronization
- UL1741 safety disconnect
- System monitoring
- Communication – wired and/or wireless



Micro-Inverter

PV panels



Micro-Inverter
One attached
to each PV
panel

DC to AC
Grid synch
UL1741
Monitoring
Comm.

- Each panel can output its maximum power
- Distributed points of failure
- Scalable



Move It - Transmission

Distributed Generation

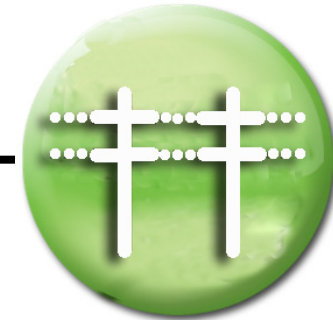
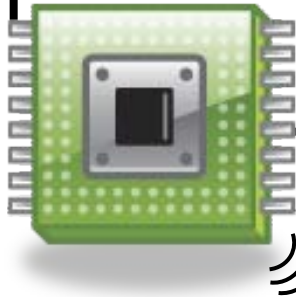
Smart Grid – energy and information flow

Inverter

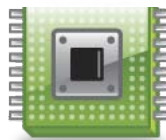
Load/
Display

Smart
Meter

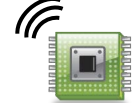
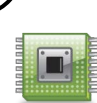
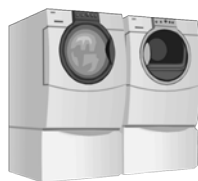
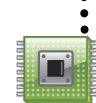
Grid



Smart meter communicates via wired and/or wireless protocol

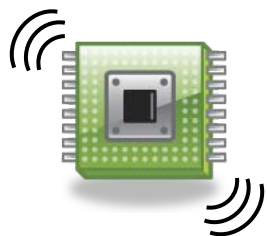


Smart
Garage





Communications



Wired and Wireless



- Low power RF (Zigbee, simple star networks, ...)
- Power line based (Smart Energy 2.0, Prime, Echelon, ...)
- Standard wire based (RS485, RS232, CAN, Ethernet, ...)

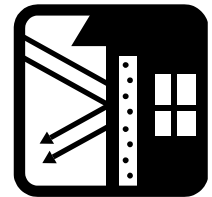




Use It - Efficiency

Batteries not included
... or needed

- **Passive Features First**
- Site Selection & Building Orientation
- Structure Size/Shape/Material
 - Insulation & infiltration
 - Reflective / vegetative roof
- Insulation and infiltration
- Window & Door Selection / Location
 - Manage solar gain
 - Natural daylight
- Energy and Daylight modeling



It is cheaper to save energy than to buy or produce it.



Use It - Efficiency

Load





Not the Answer



Outlet wall – from Gadget Venue

Power Bricks / Wall Warts

1.5 billion in US

11% of US power use

Efficiency of old units = 30%

Current Energy Star IV = 70%+

Current capability >94%

Source: Energy Star



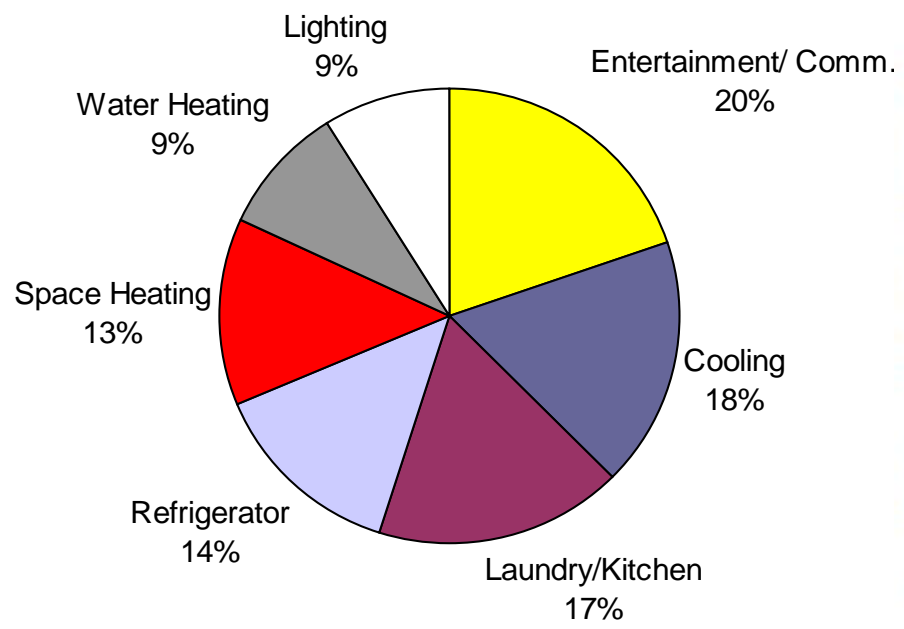
Energy

Vampire



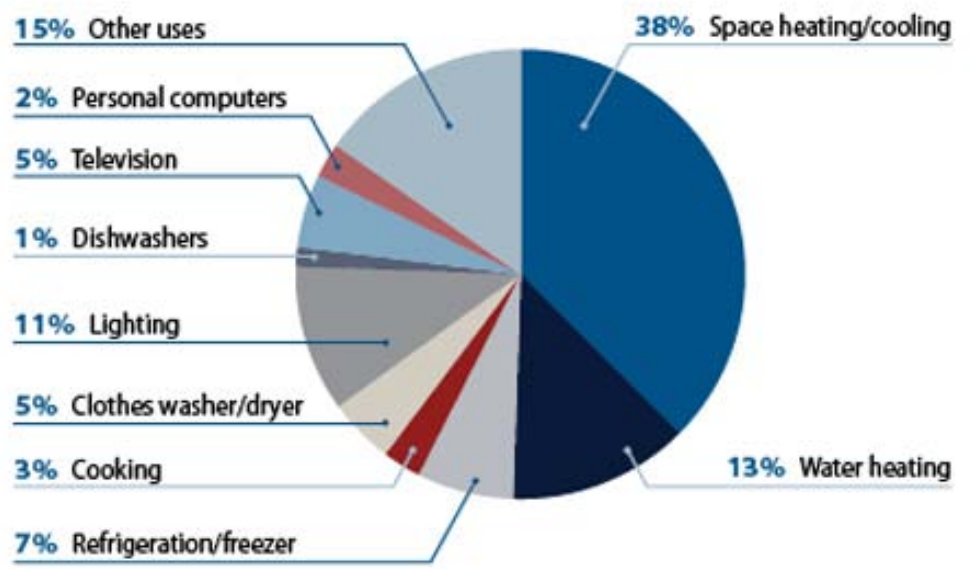


Typical Residential Use



Source: EIA 2001

Energy consumption of a typical household, 2009

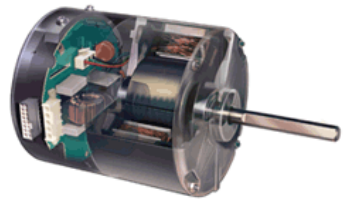


Source: enviornmentalleader.com 2009

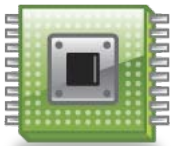
Much of the cooling load comes from waste heat from lighting and appliances



Appliances / Motors

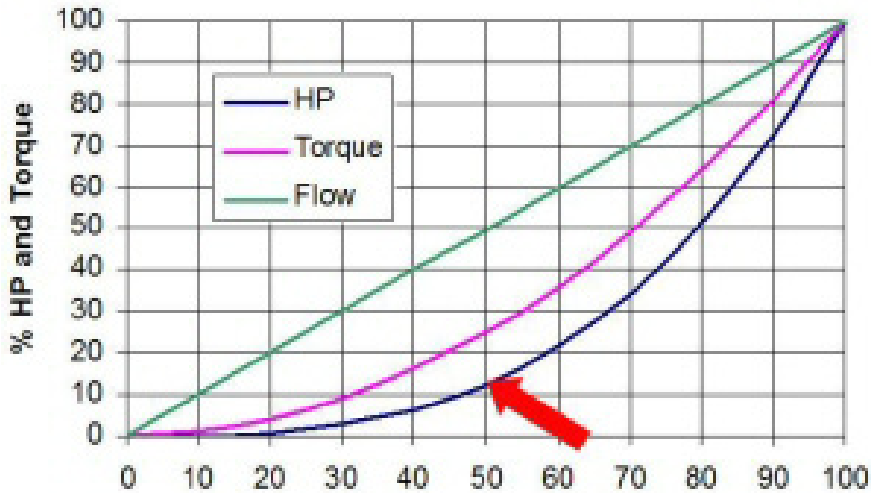


- Residential motors, used in fans, pumps, and appliances, are often only about 60% efficient
- Some new brushless permanent magnet motors (also called electronically commutated motors) are 80% efficient
- Changing to efficient motors can greatly reduce the power use of an appliance
- Variable frequency drives (VFD's) can further reduce fan/pump energy via the cube law
- VFD's allow for lighter motor components because they reduce abrupt starting forces





The Cube Law



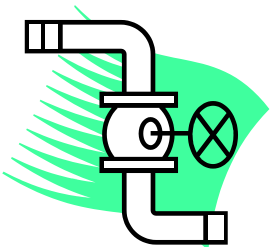
- Fan and pump power increase at the cube of rotational speed (flow)
 - 1/2 the speed = 1/8th the power
 $(.5)^3 = .125$

Source: Control & Motion, Inc. % Speed

- Pressure loss in a duct/pipe is proportional to the diameter to $(dia)^{5.2}$

- Increase from 2" diameter to 3" diameter = 1/8th the friction loss
 $(.667)^{5.2} = .121$

- Pipe price only increases at the square of diameter





Lighting Fixtures



- Natural daylight is always best
- Don't over-illuminate
- Fluorescents / compact fluorescents have very good light output / Watt and are affordable
- LED's are improving in light output / Watt and have longer lives





Lighting Control



- Turn off / dim lights when daylight is present
- Occupancy sensors to turn on lights only when people are present
- New systems are wireless and use energy harvesting to provide the power
 - Efficient ultra low power chips
 - Energy scavenging / harvesting (light, vibration, thermal)

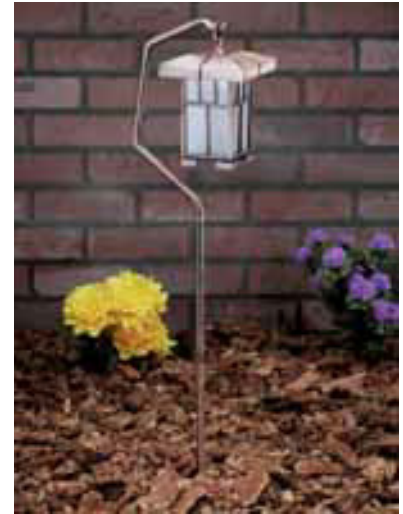




Alternative Lighting



- Or just cut the cord





Silicon for Control / Monitoring



Thermostat



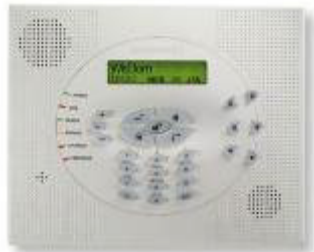
Solar Water



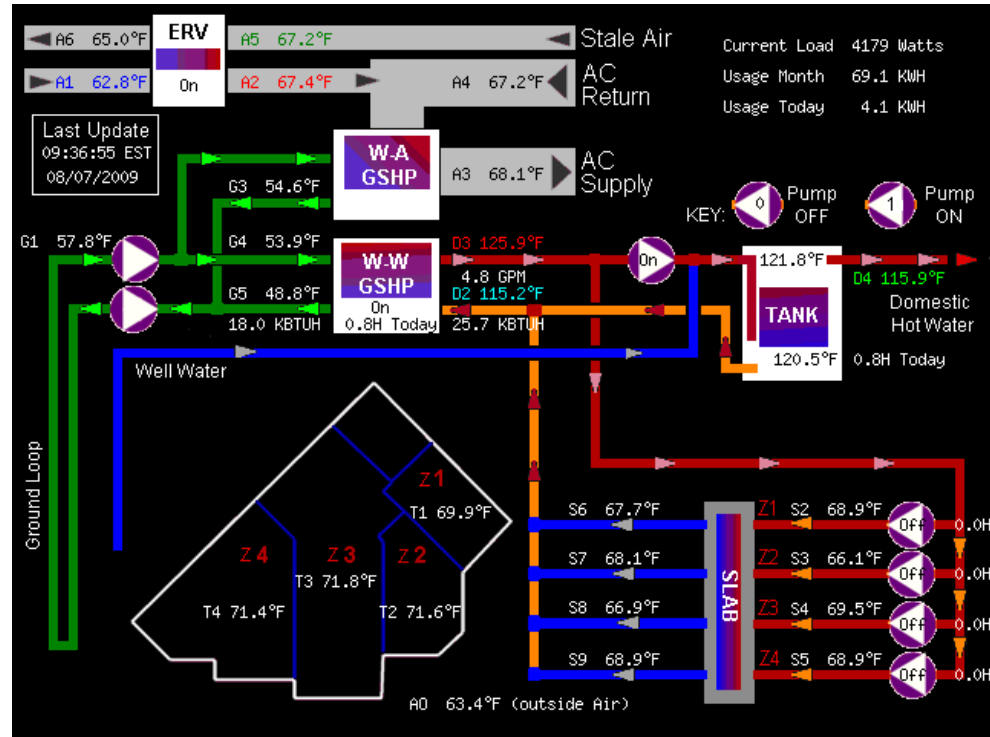
Irrigation



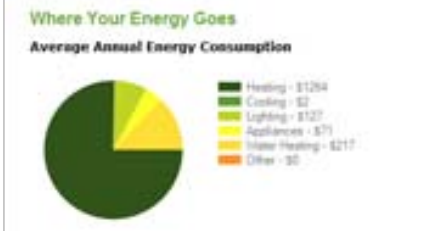
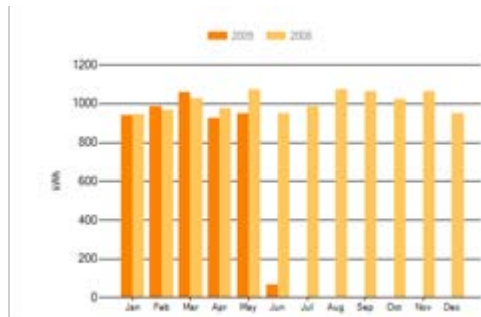
Pool



Security



- Whole House





Silicon for Inverters

- Electronic components in a modern wind turbine





U.S. DEPARTMENT OF ENERGY

SOLAR DECATHLON

2009

www.enerjazz.com/house

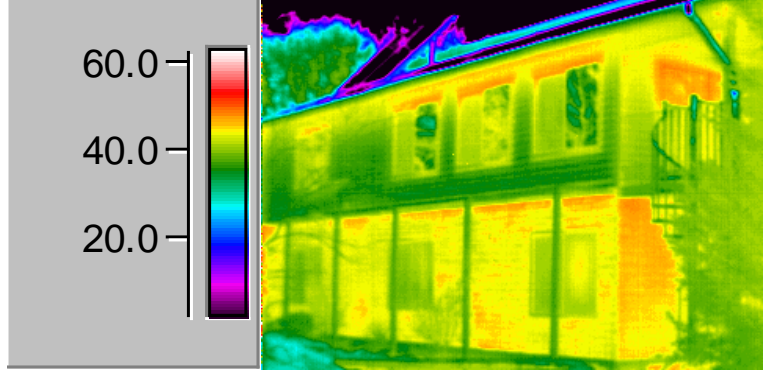




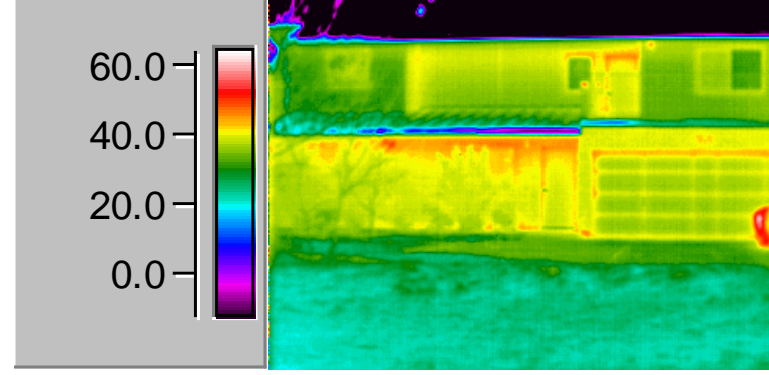
Silicon for Building Analysis

- Electronics are used in thermal imaging cameras to gauge the results of your efforts

Westbrook House - South Wall

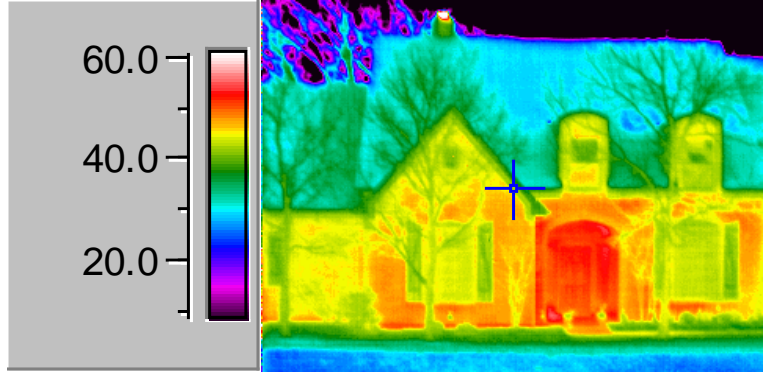


Westbrook House - North Wall

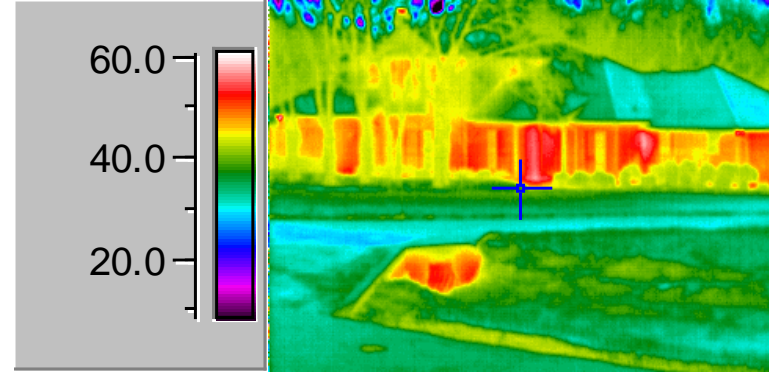


Outside Temp = 43 deg F

Standard Construction House



Standard Construction House



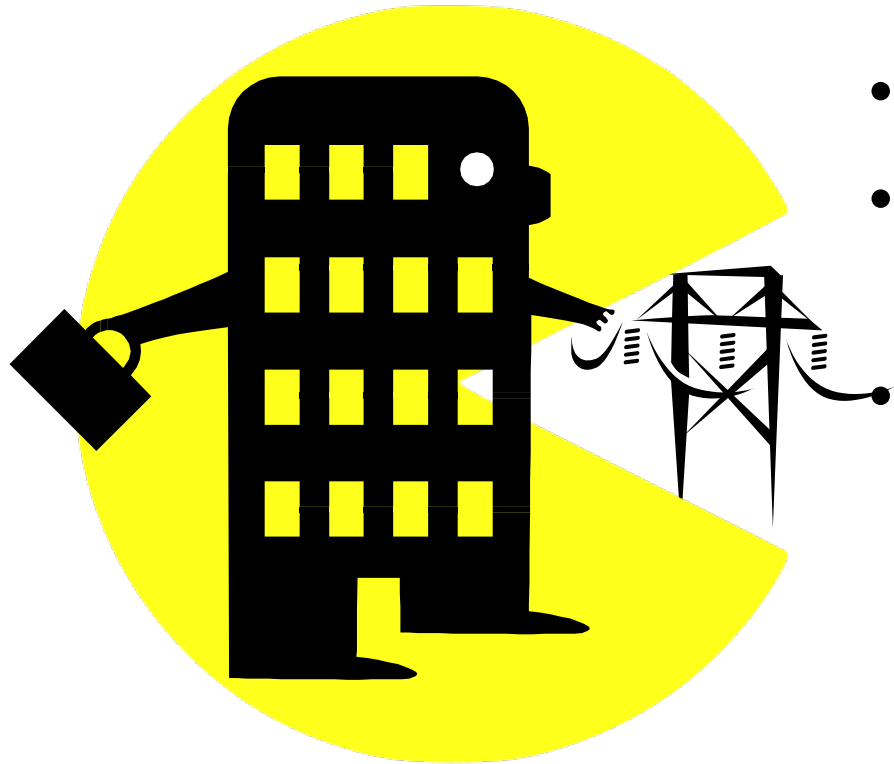


Silicon for Solar and Sustainability

- TI supplies thousands of scrap and pilot wafers per year to solar PV manufacturers
- Since 2000 those wafers have been used to produce:
 - 1.1 million square feet of PV
 - **(equivalent to 65,000 200W panels or over 17MWh of power)**



Why Buildings Matter



- Buildings consume:
- 14% of the potable water
- 40% of the raw materials
- 40% of all primary energy used in the US
- 72% of all U.S. electricity

And buildings are responsible for 39% of all U.S. carbon emissions

Sources: 2008 EIA, 2000 USGS, and USGBC



Power Management is Key



Power management products can stack energy phases to create power trains that provide stable energy for plugged in products with minimum power waste.



Power factor correction technology adapts power supply according to how much power a device needs, minimizing waste and reducing energy consumption.



Green mode controller technology senses if a device is plugged into a wall adaptor and adjusts the power supply accordingly to save over 58 billion kilowatt-hours of wasted energy per year – equal to the output of 10 large power plants!



Boost Technology elevates or reduces voltage based on specific requirements. For example, it elevates the peak voltage of a solar or fuel cell to a usable voltage level needed to power a portable application.







Battery Gas Gauge operates within 1% accuracy so consumers use almost all energy stored in the battery of a notebook PC or other portable handheld device.





Summary

- Build the right size / shape / shell
- Implement passive features first to reduce load
- Reduce friction / losses / waste
-  • Use VFD's and efficient motors
-  • Daylight first, then efficient / controlled lighting
-  • Utilize efficient electronics to reduce power use
-  • Use electronics to produce / manage / optimize power use

Make It **ENERGY**

Move It

Efficiently

Use It