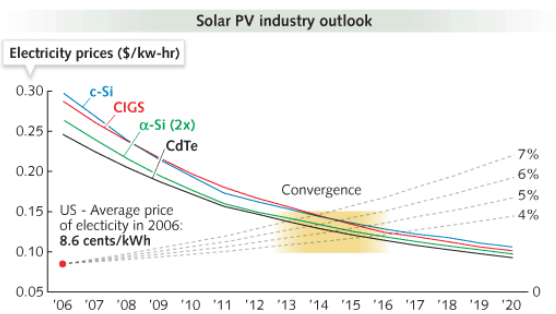
Reinventing solar power:

How photovoltaic energy production can become smarter and much more efficient

Every six hours, enough sunlight energy reaches the Earth to meet the world's energy demand for an entire year. With such a huge amount of freely available green energy , Photo-Voltaic (PV) technology has become an icon of the environmental movement. But, PV/solar has been *the energy of the future* for three decades and still accounts for less than 0.5% of the world's energy production.



WaferNews source: Stephen O'Rourke/Deutsche Bank

The challenges and opportunities in moving solar from an emerging to a mainstream energy source are several-fold. Despite the amount of power coming from the sun, PV energy is far from being a free commodity because the conversion equipment is expensive and its efficiency shows much room for improvement . This is easily achieved by using semiconductors to manage the systems . At the moment, growth in PV depends heavily on incentives, politics and a "micro-lending" model of capital investment. There is little doubt, however, that PV will someday approach price parity with fossil fuel sources. From a system perspective, deploying huge numbers of solar installations changes the energy-delivery paradigm as it will need to take into consideration factors such as grid behavior, pick-load handling, and other real-world concerns. This means that PV is at, or close to, its tipping point, and new developments in semiconductor technologies have the potential to push it over the top.

The state-of-the-art solar power system today consists of a relatively straightforward set of components and is about 10-15% efficient -when everything is working as intended. New architectures that incorporate a wide range of digital and High Performance Mixed Signal (HPMS) semiconductor technologies are creating new revolutionary architectures. These new architectures are better designed to adjust to environmental changes that diminish efficiency and also to optimize the amount of power the system can produce by monitoring and correcting the operating characteristics of its components.

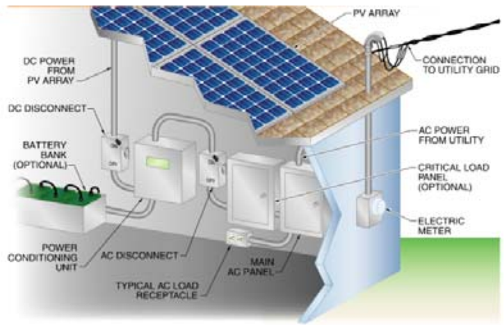
Installing solar systems that deliver more power to the grid is critical for two reasons. Firstly, PV power that is generated but not delivered to the grid will have no consumption benefit, and secondly, every kilowatt-hour (kWh) of energy saved by improving operating efficiency can avoid sending just as much CO_2 emission into the atmosphere as a kWh generated by a newly installed solar panel.

Solar electronics

NXP's low-power IC dedicated to performing the Maximum Power Point Tracking (MPPT) algorithms combined with it patent-pending algorithm can extract 30% more power from a solar panel than traditional controllers in an application such as battery charging.

In the design domain, NXP's Delta Converter architecture keeps each solar panel operating at optimal efficiency.

NXP is pioneering gallium nitrite MOSFETS use significantly less energy than traditional IGBT-based solutions because of their high switching frequencies and limited conduction resistance.



NXP Semiconductors has been improving conversion performance by developing technologies in both the hardware and software domains. It continues to create algorithms for accommodating the environmental changes experienced by solar panels and the idiosyncrasies of the PV modules themselves.

NXP also offers a range of ultra low power microcontrollers, drivers, MOSFET and other components tuned to the needs of solar that deliver higher performance and higher efficiency than competing technologies.

Energy thieves 1: Environmental effects
Advances in the ability of photovoltaic cells to convert more solar energy into electrical energy typically receive a good deal of attention, largely because the typical efficiency of a commercial PV cell remains limited to only 10-20%, depending on cell technology. But, overall system efficiency is ultimately more important and it can be degraded significantly by commonplace events such as shade falling unevenly on individual panels, or objects such as leaves, dirt, or bird droppings falling on the panels.

In most of today's system architectures, solar panels connected in series comprise the basic energy collection part of the system. Each panel produces a nominal DC voltage of about 30V. Since the panels are connected in series, the voltages are summed. A typical configuration might have 10 panels each producing 30V, which brings the total voltage to about 300V. In some systems, this voltage charges a battery that stores electrical energy for conversion into AC power by an inverter or directly used as DC power. In the majority of residential/solar farm installations, the battery is omitted and the AC output of the inverter is connected directly to the grid.

A critical assumption is that all the panels behave exactly in the same way. This is, in fact, seldom the case. First, manufacturing variations cause the PV cells inside the panel to slightly vary in the current they produce. More important are the environmental factors such as shading and dirt. Partially dirty, shaded or inoperative cells do not capture as much sunlight and therefore produce less energy and a lower current. Variations between the cells/panels lead to a significant reduction of system output power. A shaded area of 10% on one panel can reduce overall panel output power by more than 30%.

Energy thieves 2: Insufficient information
The conversion efficiency of a PV cell depends on a number of variables including the sun's intensity, the temperature of the cells, operating point, and their theoretical peak efficiency. Knowledge of these variables can be used to determine the most efficient operating point for the entire solar panel. Sensors, microcontrollers and other ICs can be used to monitor and adjust the operating voltage, a variable most easily controlled by system designers, and obtain energy gains of >10-15%, under certain conditions. This is just one example of how information and communication technology can enhance the efficiency of PV power generation. It can also add additional features like increased safety levels, simplify installations and enable better and easier maintenance.

The industry is at the beginning of a new era and therefore the most cost-effective and energy-efficient solar system architecture is yet to be determined. Distributed power–management systems seem to be on everybody's list. The overriding question is whether it is best to move energy around the system with DC voltages, or, introduce micro-inverter technology that converts DC to AC at each panel output. Regardless of the twists and turns of the system-architecture competition, NXP Semiconductors is well positioned to lead the way.

In the two distinct ways of making PV energy generation more efficient – design and superior semiconductor performance – NXP has already made significant contributions. It recently introduced the MPT612, a low-power IC dedicated to performing the Maximum Power Point Tracking (MPPT) function that optimizes power extraction in solar applications. When running NXP's patent-pending MPPT algorithm, the MPT612 can extract 30% more power from a solar panel than traditional controllers in an application like battery charging.

Winning with design and performance
In the design domain, NXP has contributed a major innovation with its DC-DC converter used at the panel level. NXP's "Delta Converter" equalizes the voltage differences between the panels in an installation. Different from other solutions in the market which process all the power produced by the PV panel, NXP's Delta Converter evens out voltage differences between neighboring panels by exchanging energy among them. When there is no difference, the converter is not active. Benefits include less energy consumed in the conversion process and higher reliability because the converter doesn't operate continuously.

Thanks to its long history expertise in high reliability electronics and high-voltage semiconductors, NXP has already developed and is developing semiconductor products that have the potential to become the workhorses of the solar economy:

- Microcontrollers for Maximum-Power-Point-Tracking;
- Wireless and power-line communication chips for inter-panel communication;
- HV drivers for DC/AC converters and LV drivers for DC/DC converters;
- Controllers, power MOSFETS and High and Low Voltage drivers for efficient DC/DC and DC/AC converters;
- Innovative diodes for bypass functionalities
- Gallium nitride MOSFETS that allow high switching frequencies with limited conduction and switching losses and therefore dissipate less power than traditional power solutions based (for example) on IGBT

These innovations are the result of NXP's decades-long passion developing High Performance Mixed Signal technologies. In a nutshell, High Performance Mixed Signal combines analog and digital technologies to give design engineers the versatility they need to create products that can dominate the next decade.

Under the hood

Semiconductor processes are the enabling technology that make the design of High Performance Mixed Signal chips possible and three NXP-developed processes are relevant to solar system architectures: The EZ-HV process produces small devices that can be operated up to 700V; the ABCD9 and CO50PMU processes have already set new performance benchmarks for conversion application up to 120V and will deliver superior DC-DC converters; and finally, the gallium nitride process mentioned earlier that results in power MOSFET with very small switching losses and conduction losses.

By integrating chips and devices developed with High Performance Mixed Signal design and process expertise, the efficiency of solar panels will further improve considerably, shortening economic break-even times, and boosting general acceptance as a common alternative for domestic and industrial applications.