Wide-Bandgap Electronics Analysis

Electrical energy constitutes 40% of total primary energy consumption in the United States, and this is only expected to increase with broad adoption of electric vehicles and the proliferation of renewables.

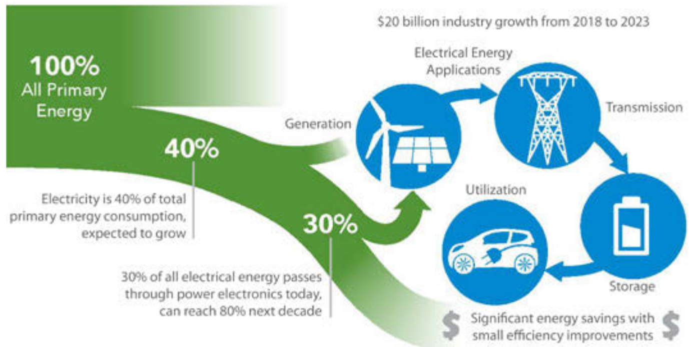
Building on its existing wide-bandgap (WBG) R&D and analysis activities, researchers at the National Renewable Energy Laboratory (NREL) are investigating new power electronic technologies based on WBG semiconductors, which are essential for advanced electrical energy generation, transmission, storage, and use. This work supports efforts by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy's Advanced Manufacturing Office (AMO) to identify solutions to address the increase in electrical energy consumption through the development of more efficient power electronic devices.

Power Electronics and the Grid

Power electronics, currently commonly made of silicon (Si), are a key component in advanced electrical energy generation, transmission, storage, and use.

Today, roughly 30% of all electrical energy passes through power electronics, and this number could reach 80% in the next decade. With the growth of electrical energy consumption, the power conversion sector is projected to grow from $52 billion to $71 billion by 2023.

NREL researchers Timothy Remo, Samantha Reese, and Andriy Zakutayev, along with NREL Associate Laboratory Director Johney Green, use computing analysis to research how much gallium oxide power electronics will cost. *Photo by Dennis Schroeder, NREL 55120*



Advanced power electronic technologies can offer significant energy savings with small efficiency improvements.

However, as electrical energy passes through these devices, there is a loss of energy. This left an opportunity for researchers to improve on the materials to increase efficiency.

Rough estimates using these numbers suggest that even modest loss reductions in present power electronic devices (5% absolute or 50% relative of peak efficiency) can lead to 1.5 Quads of energy savings, enough to power a third of all homes in the United States.

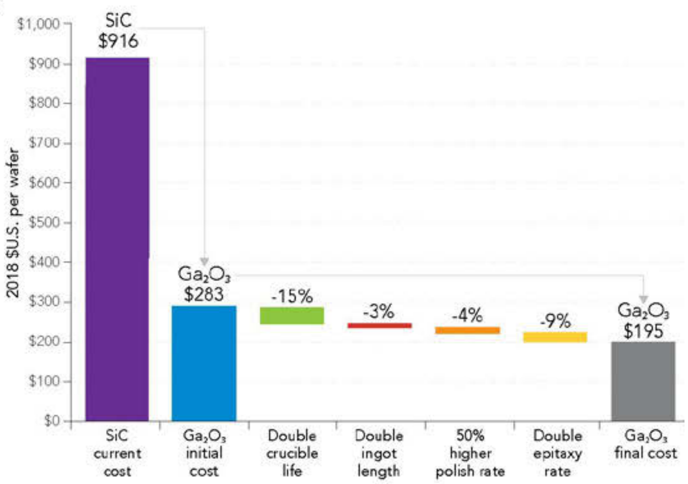
Opportunity

Reducing loss in these devices represents an opportunity to save energy and money, and researchers at NREL are working on new ways to make this a reality.

Advanced power electronic technologies may offer a solution to current challenges, enable the continued growth of electric energy consumption, and could be instrumental for the growth of the industry.

These next-generation power electronic technologies, based on WBG semiconductors, have several potential advantages NREL is working to harness:

- **Less wasted heat**
- **Improved energy efficiency**
- **Improved reliability**
- **Reduced cost**
- **Smaller system sizes.**



Read, "How Much Will Gallium Oxide Power Electronics Cost?" in *Joule* to learn more about this research.

Silicon Carbide in Power Electronic Technologies

Commercially available WBG semiconductors currently use silicon carbide (SiC). The material was developed in early-stage R&D for high-performance power electronic components that can operate at higher temperatures, voltages, and switching frequencies, and improve power conversion efficiency.

An AMO-funded collaboration between John Deere Electronic Solutions and NREL developed a technology for a cost-competitive modular engine-coolant-capable SiC inverter that can be used in multiple tractor platforms.

The research proved that hybrid-electric heavy-duty construction vehicles and other power electronic devices can benefit from cutting-edge WBG materials and components. Advancements reduced system weight and volume and improved efficiency, incentivizing new applications for these innovative materials.

This research on SiC in WBG semiconductors is foundational to developing more advanced, efficient power electronic devices.

The Potential of Gallium Oxide in WBG Semiconductors

While SiC WBG semiconductors improve power electronic technologies and are commercially available, researchers continue looking for ways to reduce costs while maintaining—or improving upon—the capabilities enabled by SiC.

WBG power electronic based on gallium oxide (Ga_2O_3) is an emerging technology that can compete with both Si and SiC.

NREL's research so far is showing that Ga_2O_3 has the potential to have a 3-5X higher bandgap, as well as a 2-3X higher operating temperature compared to silicon. In addition, research shows that Ga_2O_3 wafers could be 4.5X cheaper than SiC, with the same technical advantages.

Partnership Opportunities

The United States is currently a leader in WBG development, but the market is in early stages. NREL is looking for industry partners to continue WBG and Ga_2O_3 work to:

- **Provide industry insights**
- **Address supply chain issues related to barriers to adoption**
- **Validate models**
- **Inform industry design decisions.**

Building partnerships will allow DOE, NREL, and industry to leverage analytical data to inform design and business decision instead of the current reliance on anecdotal information.

Contact

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