Program: PowerAmerica
Release Date: February 1, 2024
Deadline for Responses: February 15, 2024, 5:00 PM EST
Submission Method: Responses should be submitted by email to:
poweramerica@ncsu.edu

Objective:
PowerAmerica seeks public input on applied research topics addressing technology gaps in wide bandgap (WBG) power semiconductor chips and electronics. Addressing these gaps can enable manufacturing that will contribute to the PowerAmerica mission of realizing energy savings and U.S. manufacturing jobs creation through accelerated large-scale adoption of wide bandgap semiconductor chips in power electronic systems. The information collected through this Request for Information (RFI) will assist PowerAmerica in developing its next **Call for Proposals (CFP). Projects selected for funding through the CFP will be included in the PowerAmerica award from the U.S. Department of Energy (DoE).**

Background and Rationale:
The DoE launched the PowerAmerica Institute under the Manufacturing USA initiative to accelerate adoption of wide WBG power chips. The institute is managed by North Carolina State University. PowerAmerica is accelerating the adoption of advanced semiconductor chips made with silicon carbide (SiC) and gallium nitride (GaN) into a wide range of products and systems. Backed by an anticipated $32 million from the DoE (supplemented by $32M in cost share) over five years, PowerAmerica is working to make these WBG semiconductor technologies cost-competitive with silicon-based power electronics and reduce their perceived risk in many applications. Education and workforce training — for community college students, undergraduate and graduate students, and working professionals — is another important element of the PowerAmerica mission.

PowerAmerica brings many of the world's leading WBG semiconductor manufacturers and end-users together with experts from top research universities and government labs to accomplish its objectives. Through participation in the PowerAmerica ecosystem, industry members grow their business by accelerated WBG product introduction to market, and university members gain by engaging in collaborative projects with industry. In addition to having solicited technical information from its 90 members, PowerAmerica is now soliciting input from industry and universities (with technical activities relevant to the PowerAmerica mission) who have not yet joined the PowerAmerica ecosystem.

In the RFI guidelines and topics that follow, PowerAmerica has outlined objectives formulated through internal planning and through informal discussions with our members and stakeholders. PowerAmerica will formulate its upcoming CFP by incorporating feedback from responses to this RFI.

RFI Guidelines:

Parties interested in responding to this RFI should first review the PowerAmerica program areas of interest, described in this document, as well as the guidelines presented below. Respondents may provide feedback in multiple program areas.

Responses should provide a discussion of the proposed topic, including a description of the current state of technology and the required improvements in technology performance, manufacturability, and/or supply chain integration needed for widespread adoption. Responses should also be supported by market and technical data when available. A response should include a discussion of key technology barriers and challenges that need to be overcome and also provide an estimate of the scale of resources and the timeframe needed to enable wide-scale industry adoption. Justification of how the proposed topic supports the PowerAmerica mission of realizing energy savings and manufacturing jobs creation through accelerated large-scale adoption of wide bandgap semiconductor chips in power electronic systems (www.poweramericainstitute.org) should also be provided.

This is *not* a *Call for Proposals* (CFP). PowerAmerica will not pay for information provided through this RFI. PowerAmerica is NOT seeking specific proposals with this RFI but is interested in soliciting broader perspectives on mission-related areas that would benefit from focused development activities. Responses to this notice are not offers and cannot be accepted by PowerAmerica to form a binding contract. Respondents are asked to focus their responses on highlighting promising approaches and topics that will benefit from development and will have a strong, lasting impact in advancing the PowerAmerica mission. Budget information is not required.

Comments in response to this RFI must be submitted to PowerAmerica at poweramerica@ncsu.edu. To be considered, comments must be provided no later than 5 p.m. EST on February 15, 2024. All documents responding to this RFI must be delivered electronically to the address above using either Microsoft Word (.doc) or Adobe Acrobat (.pdf) formats and with a file size no greater than 3 MB. PowerPoint files (.ppt) converted to Adobe Acrobat (.pdf) files will also be accepted. **Responses must be two pages or less in length**. Responses that do not meet these criteria will not be considered.

Information obtained as a result of this RFI will be used by PowerAmerica for program planning on a non-attribution basis. Information with limitations or restrictions on its use is not solicited and will not be considered. **Do not include any information that might be considered proprietary and/or confidential.** There will be no specific response to submissions other than acknowledgement of their receipt. This PowerAmerica RFI is broadly seeking non-proprietary perspectives on mission-related areas that would benefit from focused development activity, and any resulting program activities will be developed internally by PowerAmerica. Submission of responses to this RFI will not preclude a respondent's participation in future PowerAmerica programs addressed by responses to this RFI.

Program Areas of Interest:

The scope of PowerAmerica activities includes wide bandgap materials, equipment, chip fabrication, packaging/modules, passive components, application demonstrations (including grid modernization, EVs, data centers, UPS, motor drives, and other industrial uses of SiC and GaN), and education and workforce development projects. PowerAmerica is not seeking to support development of semiconductor technology areas that have not yet demonstrated technical feasibility or support technologies that are already commercialized. PowerAmerica is specifically interested in supporting topics that will strategically impact its mission of realizing energy savings and manufacturing jobs creation through accelerated large-scale adoption of WBG semiconductor chips in power electronic systems. PowerAmerica believes that the challenge of accelerated large-scale adoption of wide bandgap semiconductor chips will require a multidisciplinary approach and encourages the participation of well-established large companies, small business, start-up companies, national labs, and universities. PowerAmerica will consider supporting topics in all areas relevant to its mission. Several high-impact topics in each area in which PowerAmerica is considering investing are listed below to solicit respondent input. By no means is this to be considered an exhaustive or definitive list of PowerAmerica topics of interest.

Focus Area 1 – PowerAmerica Management and Operations

Comments not solicited.

Focus Area 2 – Manufacturing of WBG Materials, Equipment, Chips, and Modules:
Address the technology and knowledge gaps in WBG chip manufacturing that will enable industry to increase the scale of production, continue to reduce cost, and expand high volume manufacturing to higher-voltage and higher-frequency chips. Materials, equipment, fabs, and chip development activities include the following:

Example Projects

Demonstrate solutions and technologies that accelerate development in WBG materials. This includes improvement of WBG substrate growth rates while improving quality to eliminate "killer" defect densities, improve flatness, and reduce surface roughness:

- Demonstration projects to include evaluation and development of native and engineered substrates that reduce cost and secure a supply chain that meets the high demand.
- Demonstration of technologies that extend SiC substrate diameters to 200mm.
- Demonstration of technologies that extend GaN substrate diameters to 150mm.

In the area of epitaxy, demonstration projects to improve 6.5kV and above chips are solicited. Demonstration of epitaxy projects that include development of lateral GaN on silicon buffer layers to improve thermal conductivity are also solicited.

- Demonstration GaN projects that focus on buffer layers that minimize the impact of lattice mismatch and extend lateral GaN chip breakdown voltage capability to 1200V.
- Demonstration of next-generation growth equipment for the creation of bulk SiC and GaN substrates. These projects will focus on enhancing throughput, repeatability, precision, and performance.
- Demonstration to focus on developing SiC and GaN epitaxy equipment with faster growth rates, better uniformity, lower defect density, and greater thickness.

- Demonstration projects that enable high-voltage chip packages/modules essential to grid modernization and the EV charging infrastructure.
- Demonstration projects that emphasize 6.5kV and above SiC, and GaN, reliable and rugged chips:
    - 6.5 kV and above SiC chips.
    - 1200 V lateral GaN chips
    - Vertical and bidirectional GaN chips.
    - P-type doping for GaN.
    - Demonstration of solutions in high-value problems in chip processing such as:
        - ohmic contacts
        - passivation
- Additional demonstration projects could include development of high power-density and voltage advanced power chip packaging with:
    - Demonstration of improved thermal management
    - Demonstration of high voltage isolation, partial discharge tolerance, and low inductance.
    - Demonstration of integrated gate drives and control ICs that provide prognostic and diagnostic functions embedded into the package design of the power chip.

Additional demonstration projects in WBG will focus on specific processing equipment for polishing and grinding, substrate thinning, heated implantation, ohmic contact formation, etching, dielectric deposition, and metallization. These projects will have the goal of increasing SiC and GaN chip production throughput with improved yields.

- Demonstration of test, measurement, metrology, inspection, and process monitoring tools with improved accuracy to characterize SiC and GaN materials.
    - Demonstration of development of standard nomenclature/classification around definitions of defects
    - Demonstration of techniques for non-destructive chip characterization for both epi and substrate

- Demonstration of tools to detect defects, epitaxial thickness and doping uniformities, and electrical properties.
- Demonstration of tools to perform in-situ quality verification during the manufacturing process to accelerate throughput and production.
- Demonstration of tools that emphasize WBG development while emphasizing operator safety and equipment requirements, particularly when operating and evaluating prototype power electronics at medium-voltage levels.

Focus Area 3 – Applications and System Demonstration Projects in Power Electronics: *Address the knowledge and technology gaps in WBG application demonstration projects that will enable power chips and modules to have a transformative impact in the following critically important applications:*

Example Projects in Mobility, Traction, and Transportation:

- Demonstration projects that emphasize efficiency improvements in transportation and mobility. This includes not only passenger vehicles but also mass transit, rail, and aerospace.
  - Optimized traction control algorithms to take advantage of WBG that enable WBG uptake with efficiency improvements over existing state-of-art mobility motor-drive systems.
  - Optimized topological designs to take advantage of WBG switching speed/efficiency and address reliability issues in traction and propulsion motors.
  - Optimizing motor efficiency with frequency and algorithms that run at higher switching frequency than existing state-of-art.
  - Demonstration of technologies that mitigate EMI/RFI generated in traction and propulsion systems used in transportation.
  - Demonstration of grid-interactive bi-directional battery charging systems and topologies for support of interface to grid resources.
  - Demonstration projects involving passive component development to support the integration of WBG chips and topologies into the above-mentioned projects.
- Demonstrate WBG power modules and components for implementation in WBG inverters and DC/DC converters used in traction, charging, and mobility applications.
  - Application requirements for converters and motor drives that employ WBG designs with emphasis on reliability, robustness, and EMI/RFI reduction.
  - Developing insulation systems and requirements that enable WBG designs for high voltage batteries in mobility.
  - Demonstration of modular and re-use of power-stages within propulsion and battery charging with emphasis on WBG integration
- Development of robust and effective gate drives for high dV/dt WBG switching capable of maintaining isolation during high dV/dt transitions
  - Demonstration of high temperature and extreme temperature applications for gate drive circuits.
  - Demonstration of WBG-specific gate drivers that integrate advanced safety and sensing technologies to improve reliability.
  - Documentation of best practices for applications of gate drivers with emphasis on successes in well-known systems as a guide for future designs
  - Development of voltage-isolation interfaces that enable gate drive communication while maintaining reliability for high dV/dt applications.
- Demonstration of supporting WBG technologies for vehicle electrical architectures: 48V and above.
  - Development of a new generation of DC contactors, solid-state switchgear, next-generation contactors, high-voltage fuse technology compatible with WBG power modules, voltage isolators, and related infrastructure to support high voltage power processing/battery charging in mobility and propulsion.

    - Identifying electrical architectures that allow traction and charging systems to work with fewer components.
- Demonstration of WBG aerospace applications
    - Development of medium and large propulsion motors for aircraft and spacecraft employing WBG inverters
    - Demonstration of all-electric aircraft propulsion and aircraft power systems
        - Demonstrate inverter reliability in adverse thermal environments.
        - Demonstrate reliability in adverse radiation environments.
        - Demonstration of improved packaging and power density
    - Development of advanced packaging technologies for uptake of WBG chips in aircraft and spacecraft
        - Demonstration of integrated motor inverter packages for propulsion/space motor/compressor applications
        - Demonstration of improved propulsion systems that use WBG and support human-rating for aerospace applications.
        - Demonstration of FAA-approved DO-160 systems.

Example Projects in Grid Modernization

Grid modernization projects will emphasize development of WBG based circuits to support efficient grid modernization and distributed generation at 6.5 kV and above voltages.

These projects will integrate WBG chips into grid modernization applications such as grid forming and following inverters, solid-state transformers (SST), solid state circuit breakers, energy storage systems, and fast EV charging infrastructure. WBG based circuits that enable distributed solar generation, wind power, and bidirectional energy storage will be developed.

- Demonstration projects for bidirectional or unidirectional converter topologies utilizing 6.5kV and above chips.
    - Demonstration projects for higher power modular and scalable converters
    - Bidirectional switch technology to enable:
        - Reliability and efficiency gains for substation switching.
        - Reliability and efficiency of solid-state circuit breakers.
- Demonstration of grid-forming technologies that apply WBG chips.
    - Projects will demonstrate DC/AC conversion and ESS (energy storage systems) that use WBG to improve performance and reliability.
    - Solid state transformer topology architectures operating with WBG at MV level (11kV - 3.3kV) and LV level 480VAC.
    - Resonant, phase-shifted, dual active bridge converters for solid state transformers that emphasize WBG adoption.
    - DC microgrid research to reduce transmission losses and make the grid more resilient though WBG applications.
- Packaging Demonstration Projects for Grid Infrastructure
    - Standardized power semiconductor packaging technologies for LV, and MV SiC chips.
    - DC distribution packages that enable WBG switchgear and protection
- Reliability Demonstration Projects for Grid Infrastructure
    - Short circuit protection for new grids and other safety features.

- Demonstration projects with power distribution-class capacitors, inductors, and magnetic components optimized for WBG.
- Demonstration of packaging for high-frequency using high-voltage passives to enhance reliability and robustness.

Example Projects in Energy Efficient Data Centers and Industrial Applications:
Demonstration of single and three-phase off-line power supplies to achieve greater-than 98% efficiency in offline power for data center servers. Development of WBG uninterruptible power supplies (UPS) with improved efficiency and reliability, and address packaging, electromagnetic interference (EMI), and thermal concerns to accelerate their adoption.

- WBG based single and three phase converters with efficiency exceeding 98% for 3kW and 6kW class server power systems.
- Packaging and magnetics development to enable high switching frequencies for data center power supplies to fully realize the WBG potential.
- 48V to 1V power conversion solutions
    - Common Digital Control techniques for current share converters (>4 parallel, >50A at >1 MHz switching)
    - High voltage (approximately 1kV) to 56 or 48V at the server rack
- Demonstration of data center packaging with improved thermal management and power density exceeding 1kW for a 1/8th power brick.
    - Demonstration of data center circuits switching above 1 MHz

Example Projects in Energy Efficient UPS

- Demonstrate reliable WBG based UPS systems to enable efficiency, higher voltage conversion, and reduced/smaller passive component count through efficient high switching frequency operation.
    - Address the challenges of increased EMI and dV/dt stress on passives and transformers.
    - Address reliability due to high frequency WBG based system operation as applied to UPS applications.

Example Projects in Consumer and Industrial Variable Frequency Drives
Demonstration projects in this area include not only the development of low and medium voltage WBG based motor drives for HVAC and industrial applications but also WBG-enabled energy efficiency gains in heating, ventilation, and air-conditioning (HVAC). Demonstration projects can also encompass industrial processes using variable frequency drives (VFD) for industrial heating.
These projects will address WBG adoption challenges such as dV/dt induced common-mode noise, bearing currents, and radiated electromagnetic interference (EMI). Demonstration of packaging technology using WBG chips can include power density and efficiency improvements for motor drive integration with the electric motor.
Projects involving high frequency passive and magnetic circuit components that enable efficient high-power density WBG motor drives and motor drive integration with the electric motor will also be developed.

- Demonstrate modeling, simulation, design of reliable WBG-fed motors for HVAC components including compressors, chillers, and air handlers.
- Demonstrate power density and efficiency enhancements over state-of-the-art silicon, and WBG based VFD technologies that achieve 5% efficiency improvements over existing state-of-the-art VFDs.
- Demonstrate modules and circuit topologies to integrate WBG chips into low and medium-voltage Variable Frequency Drives including bi-directional and regenerative capable drives.
- Develop, evaluate, and optimize filtering and EMI mitigation strategies for industrial and consumer variable frequency WBG motor drives.
    - Demonstrations include mitigation of dV/dt switching transients with improvements in reliability.
    - Demonstrations that accelerate adoption of WBG motor drives in VFDs.
    - Demonstrations of reliability improvements due to the mitigated impact of dV/dt on the motor/insulation system.
    - Demonstration of advanced thermal capabilities for high power density motor drive packaging and for motor drive integration with the electric motor.
    - Demonstration of high frequency passive and magnetic circuit components that enable efficient high-power density WBG motor drives.
- Demonstrate solutions that fill technology gaps in power conversion high frequency components such as DC link capacitors, resonant capacitors, efficient inductors, and transformers. Demonstration projects should create technical advancements in these components to enable high voltage, high frequency, and maintain dielectric and voltage standoff capabilities to enable inherent strengths in WBG chips.
    - Enabling technologies in dielectric structures for capacitance
    - Capacitor reliability testing for high frequency DC supply ripple.
    - Physics of Failure analysis of passives and mitigation for WBG applications
    - High performance transformer modeling and winding arrangements for high power density transformer implementation
    - Advanced core modeling and leakage flux estimation for high performance planar transformer demonstrations
- Demonstration of WBG power chip modules and emphasis on integration of high frequency modules into converter systems.
    - Integration of high-current busbar and passives into PCB structures with emphasis on reliability and power density improvements
    - Demonstration of high reliability WBG chip module construction
    - Integration of power modules into converters with minimal excess stray inductance and capacitance.
    - Demonstration of WBG capable gate-drivers that improve reliability and integration of WBG chips into existing applications.
- Characterization and or development of film capacitor technology under stresses encountered in WBG converters.
    - Physics of failure of capacitor packaging
    - Development and demonstration of dielectric materials and processes for capacitor construction
    - Thermal performance enhancement of capacitor structures

    - Packaging to reduce stray inductance of capacitor structures and packaging.
    - Development of technology that increases storage density > 10uF/in3.
- Demonstration of improved reliability and ruggedness WBG-based inverter drives and power converters.
    - Perform physics of failure analysis of power modules and thermal systems for development of more robust module packages
    - Develop high voltage capable insulation systems that resist corona discharge breakdown.
    - Demonstrate insulation and winding configuration improvements addressing insulation breakdown in motor windings fed by WBG converters.
    - Analysis and design mitigations of WBG chip characteristics related to high dv/dt damage and breakdown in passives and windings.
    - Traction inverters operating above 600V and demonstrating reliability with respect to dV/dt induced noise on motor windings, insulation breakdown, and bearing current leakage.

Focus Area 4 – GaN Pilot Line and Other WBG Technical Activities:
The RFI seeks input to support a power GaN R&D feasibility and low-volume chip production pilot line to prototype next generation design and fabrication innovations:

- US Gallium-Nitride foundry development that leverages existing high-volume 150 mm or 200 mm silicon or GaN RF chip fabrication and addresses technology gaps that prevent high-volume manufacturing of GaN power chips.
- GaN Power chip and process integration transitions into a GaN foundry or fab that enables high-volume US manufacturing.
- Development of GaN process blocks that are compatible with fabrication in commercial fabs to facilitate transition to volume manufacturing.
- Leverage of GaN fabrication synergies with CHIPs act and other public and private semiconductor manufacturing initiatives to accelerate commercialization and maximize security of supply and resilience benefits.
- Exercise of the GaN chip pilot line through execution of GaN R&D short-loop process block development and chip projects.

This RFI solicits input in other power WBG Technical Activities including but not limited to Manufacturing of Materials, Tools, Devices, Modules, and Applications and System Demonstrations. Development of additional WBG technologies, not covered elsewhere in this RFI, include aspects of power SiC and GaN chip design, fabrication, testing, modules, reliability and ruggedness, as well as application aspects including automotive and rail traction, on-board chargers, fast chargers, converters, bidirectional power flow, photovoltaics, wind power, mobile and consumer electronics, defense and aerospace, telecom infrastructure, flexible alternative current transmission systems (FACTS), high-voltage DC systems (HVDC), microgrids, energy storage, industrial and consumer motor drives, UPS, and data centers.
The RFI solicits input in all power WBG areas including aspects of:

- Transportation (Electric and hybrid vehicles, rail traction, heavy duty electric and hybrid vehicles, vehicle chargers, on board chargers, more electric aircraft, electric ship, space, etc.)
- Renewable and Clean Energy grid integration (Photovoltaics, wind applications, grid-tied energy storage, Natural Gas Combined-Heat-and-Power etc.)
- Power delivery grids and Microgrids (DC or AC), and their integration with suitable stability, power quality, fault protection, and resilient uninterrupted power
- Industrial motor drives and HVAC
- Enterprise equipment, data center/telecom (48V front-end AC/DC, PoL DC/DC, etc.), power supplies
- Consumer power supplies (home appliances, laptop adapters, chargers, LED drivers, Class D audio amplifiers, etc.)
- Wireless power (mobile chargers, EV/HEV chargers, medical chip chargers, etc.)
- High power medical equipment
- Industrial cooking, heating, and welding

Focus Area 5 – Education and Workforce Development (EWD):
Address gaps in semiconductor and power electronics education and workforce training to meet the growing need across the U.S. for knowledgeable, well-trained engineers, technicians, and a broad range of manufacturing workers. The EWD program will address knowledge gaps and strengthen education programs for students at all levels — community college, career technical training, university undergraduates and graduates, and up through and including working professionals. EWD activities can include curriculum development, special coursework, laboratory equipment to support training, internships and apprenticeships, bootcamp-type experiences, train-the trainer, scholarships, stipends to support learners at all levels, and novel activities not listed here. The program also seeks to involve more women, veterans, rural populations, Native Americans, and other underrepresented minorities in these EWD activities. EWD activities can include the following and other concepts received in response to this RFI:

- Developing course and laboratory curriculum, textbooks, tutorials, demo kits, instructional material, etc. Leveraging, expanding, or adding WBG content to existing power electronics education programs will also be considered.
- Exposing upper-undergraduate students to WBG power electronics professional activities and internships that inspire them to seek graduate education and career opportunities in WBG power chip and electronics areas.
- Supporting workforce development for professionals and practitioners through continuing education. Materials to be developed may include technical seminars, extended tutorials, short courses with hands-on laboratory or manufacturing experience, application notes, reference design documentation, and online professional training programs.
- Launching technician training programs that address the skills needed to expand U.S. semiconductor manufacturing. These can range from technician training for metrology skills, logistics, quality control, and equipment maintenance and repair to vacuum system

mechanics, electrical-mechanical repair, and various other skills employed in the semiconductor, power electronics, and microelectronics manufacturing supply chain.

- Providing activities aimed at high school graduates, associate degree holders, and those with military training or other on-the-job experience; opportunities for training existing or returning workers and opportunities that target military veterans and those leaving military service are of particular interest.
- Partnering with or otherwise leveraging existing, successful ongoing EWD programs in the public or private sectors that match the PowerAmerica objectives and have synergistic outcomes.
- Using social media or other public communication channels to increase the visibility and awareness of the semiconductor industry and the well-paying, high-impact career opportunities available to those with the proper skills and aptitudes.
- Creating train-the-trainer programs aimed at community colleges, career technical training instructors, and others.

Information on other relevant high-impact education activities, not listed in this RFI, is also solicited: novel approaches, innovative use of technology, augmented/virtual reality, regional place-based programs, enhanced recruiting for underrepresented audiences, and other methods and approaches are sought.

Closing Comments

PowerAmerica welcomes public input through response to this RFI and looks forward to working with the wide bandgap semiconductor chip and power electronics communities to design a highly relevant, high-impact program that strongly supports the PowerAmerica mission of realizing energy savings and manufacturing jobs creation through accelerated large-scale adoption of wide bandgap semiconductor chips in power electronic systems. PowerAmerica thanks you for providing your valuable input in response to this RFI.