PowerAmerica:
Next Generation Power Electronics Manufacturing Innovation Institute

Call for Projects for
July 1, 2018 – June 30, 2019

Issue Date:	Monday, October 23
Submission Deadline for Concept Paper: https://ncsu.infoready4.com	Friday, November 10
Response (Invited/Not Invited Notification)	Monday, November 27
Submission Deadline for Full Applications: https://ncsu.infoready4.com	Friday, December 22
Expected Date for Selection Notifications:	To be announced
Expected Timeframe for Project Negotiations	To be announced
Project Start Date	July 1, 2018

General Submission Information

- Questions regarding this funding opportunity can be submitted on the PowerAmerica website. Answers will appear publicly: https://www.poweramericainstitute.org/2017-call-for-projects-questions-and-answers/
- **Do not include any proprietary information in the Concept Papers**.
- Concept Papers are mandatory for full proposal submission and the deadline is firm. An Encourage or Discourage recommendation will be provided to applicants.
- **Full Proposals will only be accepted from Invited Concept Papers.**
- We regret that Discouraged Concept Papers will not receive any further information.
- Full Proposals will not be accepted if a Concept Paper was not first submitted.
- PowerAmerica will not review any proposals that are not submitted through the submission website.
- If an application is selected for subaward negotiations, it is not a commitment to issue a subcontract. It is imperative that the Applicant/Selectee be responsive during subcontract negotiations and meet negotiation deadlines. Failure to do so may result in cancellation of any subsequent sub-contract negotiations and rescission of the selection.

Revision 1-October 25, 2017

TABLE OF CONTENTS

I. Summary 3
II. Call for Projects Description 5
A. Background 5
B. Applications Specifically Not of Interest 6
C. Concept Papers 6
D. Full Proposals 8
E. Evaluation Criteria 10
III. Types of Projects 12
A. Focus Area 2: Foundry Operations and Devices 12
2.1 Silicon Carbide Open Foundry Infrastructure Development 12
2.2 Gallium Nitride Open Lateral Power GaN Foundry Infrastructure Development 13
2.3 Next Generation Silicon Carbide Devices 13
2.4 Gallium Nitride Power Devices 14
B. Focus Area 3: Packaging, Power Electronics Foundry, Test & Reliability 15
3.1 Power Module Packaging 15
3.2 Reliability and Testing Services for SiC and GaN 15
C. Focus Area 4: Accelerating WBG Adoption for Power Electronics Applications 17
4.1 Transportation and Energy Constrained Mobile Systems 17
4.2 Renewable Energy Applications and Power Electronics for Energy Exploration 19
4.3 Energy Efficiency for Communications, Digital Systems and Data Centers 20
4.4 Enabling Subsystems for Medium Voltage Systems and Energy Efficient Motor Drives 23
4.5 Advanced Power Grid Continuity, Power Quality, and Fault Protection 24
D. Focus Area 5: Education and Workforce Development 26
5.1 Documentation of Design and Process for GaN and SiC Based Devices 27
5.2 Short Course Development 28
5.3 Technology Transition Projects for WBG Semiconductors and Power Electronics 28
5.4 Development of Undergraduate and/or Graduate Teaching Labs 29
5.5 An Open Call for Education and Workforce Development Projects 29
5.6 Outreach to Late-Undergraduate and Early-Graduate Students for Recruitment to WBG programs at PowerAmerica Member Universities 30

I. SUMMARY

Concept Papers	Mandatory Concept Papers for all proposed projects are submitted using the InfoReady submission website: https://ncsu.infoready4.com The Concept Paper should be submitted as a single pdf document plus a PowerPoint file. Only one (1) Concept Paper per division/site will be accepted from any business organization. Multiple faculty from a single university may submit Concept Papers. Only one (1) Concept Paper per faculty may be submitted. After review of the Concept Papers, PowerAmerica will give applicants a simple “Encourage” or “Discourage” recommendation for submitting a Full Proposal. We regret that Discouraged Concept Papers will not receive any further information. Concept Papers should not contain any proprietary information. Note: Projects are expected to produce tangible results including qualified devices, operating hardware, or products that can be transitioned to U.S. manufacturing. Paper studies or engineering analyses are not suitable for this program. All university technical projects are required to involve two undergraduate students in the work plan. Concept papers over the designated page limit and not conforming to the stated format will not be accepted.
Full Proposal	Full Proposals will be similar to the Concept Papers, but with a more in-depth technical project description. In addition, a cost share commitment letter, detailed Budget and Budget Justification, and Statement of Project Objectives (SOPO) with quantitative milestones are required. Templates for the required budget & budget justification, quad chart, and SOPO can be downloaded from the PowerAmerica website. (https://www.poweramericainstitute.org/2017-call-for-projects/) Information that is proprietary, confidential or a trade secret should be clearly marked. Only one (1) Full Proposal may be submitted from each division/site of any business. Multiple faculty from a single university may submit Full Proposals.
Expected Award Amounts	Throughout this document, the dollar amounts listed are the funds that will be provided by PowerAmerica to each organization of the project team. **All projects require a minimum 1:1 net cost match from the applicant team.** Suggested maximum project dollar amounts per organization shown are estimates only, and will be adjusted based on the quality of the proposal. **Proposals with funding requests exceeding the PowerAmerica limits for any organization within the team will not be considered.** **For organizations participating in multiple PowerAmerica BP4 projects, the maximum dollar amount is the sum of the funding received from the multiple projects.**
Types of Funding Agreements	**All organizations on the project teams are required to become members of PowerAmerica as a condition of receiving an award.** Selected projects will be made as Assistance Subawards from NC State University and will include flow down terms and conditions from the Cooperative Agreement between NC State and the United States Department of Energy.
Period of Performance	July 1, 2018 – June 30, 2019
Eligibility	**All proposals should have an active project team member with U.S. manufacturing presence on the subject of the proposal.** All project team organizations are required to be located in the U.S. All work must be performed in the U.S. and must have direct relevance to the U.S. manufacturing that is the subject of the proposal.
Cost Share Requirement	A minimum of 1:1 net cost match is required on all projects. Industry may provide some or all of the cost match for their university or National Lab team members.
Proposal Development Costs	Costs incurred in developing the proposal to this Call-for-Proposals cannot be reimbursed. For current PowerAmerica performers, costs incurred in developing the proposal cannot be included in their current projects including as cost share.

Multiple Applications and Awards	Businesses: Only one (1) Concept Paper can be submitted from each division/site of any business organization. Only one (1) Full Proposal can be submitted from each division/site of any business organization. Only one FA 2 through FA 4 award will be made to any division/site of any business (whether individual or as part of a team). Universities: Multiple faculty from a single university may submit FA 2 through FA 4 concept papers. Multiple faculty from a single university may submit FA 2 through FA 4 full proposals. Only one (1) Concept Paper per faculty may be submitted. No faculty will receive more than one award in FA 2 through FA 4 (whether individual or as part of a team). A single additional award in FA 5 can be made to a recipient in FA 2 through FA 4.
Teaming	**Teaming among companies with complementary capabilities or in adjacent sectors of the supply chain is strongly encouraged**. **Universities and National Labs are also strongly encouraged to team with industry** to ensure that research goals are driven by U.S. manufacturing needs, and that a clear pathway to commercialization exists**. For University and National-lab organizations that are part of a project team with industry, there will be an industry award plus additional University/National-lab awards per dollar amounts suggested in the focus area description. For teams of two or more companies, each team member will receive a separate award per maximum dollar amounts suggested in the focus area description. All team members are required to become members of PowerAmerica to receive funding.**
Membership, Bylaws, Intellectual Property	Information on Membership and Bylaws is posted online at: (https://www.poweramericainstitute.org/membership/apply-to-be-a-member/). The Intellectual Property Management Plan (Article VI of the Institute bylaws) governs the treatment of Intellectual Property and the rights between the Institute and its Members. Intellectual Property rights between DOE, the Institute and its Members are covered by the terms of the Cooperative Agreement. Each Member retains all rights to any intellectual property invented or produced prior, to or outside of, PowerAmerica-funded research. Each Member retains title to Institute Intellectual Property solely created by its own employees/contractors/agents. Members are joint owners of Institute Intellectual Property developed jointly by those Members. Institute Intellectual Property must be disclosed in writing to all Members.
Export Control and ITAR	Organizations are required by law to comply with Export Control regulations. PowerAmerica does not place any restrictions on publication. PowerAmerica will review papers and presentations generated by funded projects before publication to review for patentability and inadvertent disclosure of proprietary information. Organizations will inform PowerAmerica if there is a need to restrict publications for U.S. competitiveness, or for commercial purposes.
Summary	This call for projects is primarily focused on the development of advanced wide bandgap power semiconductor technologies, power electronics architectures and assemblies, and packaging and manufacturing processes with the potential to improve performance and lower cost. Demonstration of WBG devices in high volume, commercially viable, power electronic applications is also desired. Primary metrics used to judge the projects include potential to: ● Accelerate the adoption of wide bandgap (WBG) power electronics ● Lower the cost of WBG devices and power modules ● Demonstrate the system level advantages of WBG devices in power electronics applications ● Demonstrate the reliability of WBG systems ● Clear a pathway to commercialization ● Impact U.S. manufacturing competitiveness ● Impact workforce development and education ● Production of U.S. engineers with expertise in WBG power electronics ● Address technological gaps linked to the needs defined in the PowerAmerica roadmap and identify new knowledge gaps to be addressed

II. CALL FOR PROJECT DESCRIPTION

A. Background

PowerAmerica (the Institute) is part of Manufacturing USA. It is supported by the U.S. Department of Energy's Advanced Manufacturing Office (AMO) and investments from industry, state, university, and other partners. The Institute is a public-private partnership committed to increasing technical capabilities, domestic production, supporting manufacturing, and creating jobs across the U.S. wide bandgap (WBG) semiconductor industry. The purpose of the Institute is to accelerate the commercialization of WBG semiconductor power electronics. PowerAmerica is led by North Carolina State University in Raleigh, NC.

This Call for Projects is focused on enabling U.S. industry to develop advanced wide bandgap power semiconductor devices, power electronics architectures and assemblies, and packaging and manufacturing processes with the potential to improve performance and lower cost. Demonstration of WBG devices in high volume, commercially viable, power electronic applications is also desired. The competition for wide bandgap semiconductors is essentially silicon power electronics. WBG proposals need to show not just clear technical advantages, but also the economic, operational, and system level cost benefits over silicon, in a given application. The focus of the Institute is on projects that have a manufacturing strategy and additionally, help support the U.S. WBG supply chain.

Large-scale adoption of WBG power electronics is sensitive to pricing, perceptions of reliability, the availability of devices and modules, and the knowledge base of how best to design devices, modules, and systems that can exploit the superior physical characteristics of wide bandgap semiconductors. Furthermore, workforce development and education activities are critical for maximizing U.S. competitiveness as well as creating a pipeline of trained professionals to support this growing industry.

The Institute strongly encourages teaming between companies and between companies, national laboratories and universities as an effective strategy for the successful advancement of the technology. Teams with access to adjacent supply chain technologies, vital technical expertise or unique facilities can accelerate system development, build long-lasting partnerships, and strengthen the WBG ecosystem.

PowerAmerica focuses on projects that will advance the state of readiness beyond the concept feasibility stage. Component validation and prototype demonstrations that help to quantify the system level benefits of WBG power electronics are of great interest. In particular, PowerAmerica addresses gaps in knowledge and technology to enable manufacturing that contributes to its mission of realizing manufacturing jobs creation and energy savings through accelerated large-scale adoption of WBG semiconductor devices in power electronic systems. **Basic science and exploratory scientific research are not appropriate for this program.**

Participation by Foreign Firms
Foreign owned firms may apply, provided they have substantial manufacturing and operational facilities and staff based in the U.S. A U.S. sales and marketing operation of a Foreign Firm is not eligible. **All work must be performed in the U.S.**

B. Applications Specifically Not of Interest

PowerAmerica does not have the capacity to fund:

- Incremental improvements to, or combinations of, existing products and technologies, wherein no significant advances in understanding or reductions in technical uncertainty or cost are achieved
- Devices other than SiC and GaN wide bandgap power semiconductor devices
- WBG materials and epitaxy development are outside of the scope of this program
- Power converters and inverters for low volume and niche applications without a compelling market justification
- Vertical GaN development (because it is at a low level of technical maturity)
- Analog RF (Radio Frequency) devices and applications (except for switch mode envelope tracking applications)

C. Concept Papers

No proprietary information should be included in Concept Papers.
Documents must adhere to the following format:

- Page size – 81/2 x 11 inches
- Margins – 1 inch
- Spacing – single
- Font – Times New Roman 12 point

Concept Papers must be submitted as two separate files:
Items 1 through 6 as a single PFD file (Six pages maximum, including cover)
Item 7 as a PowerPoint file

1. Cover page (1 page)
    - Project title
    - Applicant organization
    - Point of contact name and full contact information
    - Team members (if applicable)
    - Focus Area of proposed project (i.e. FA 2, 3, 4, 5)
    - Funds requested and cost share to be provided
    - Statement that applicant understands the membership requirement. Indication of the intended level of membership. (https://www.poweramericainstitute.org/membership/apply-to-be-a-member/)
2. Technical project description (1-2 pages max)

- Describe the technical and or economic challenge addressed by the project
- Describe the technical approach to be followed and the facilities and equipment to be used
- Describe the innovation and how it represents an advancement over the current practice
- Describe technical and other risks and describe risk mitigation approaches
- Describe how the proposed work addresses knowledge and technology issues or gaps to enable large-scale manufacturing of WBG semiconductor devices and insertion in power electronic systems.
- Describe the primary deliverable(s) and how it advances the Institute objectives
- Identify SMART (specific, measurable, achievable, relevant, time-bound) metrics.

3. Commercialization approach including target market, product or manufacturing insertion opportunity, competition, barriers to market penetration, impact on U.S. competitiveness. Please include information about the expected market demand in terms of unit quantities in the one to five-year time frame, opportunities for system level cost reduction over comparable silicon solutions, and what products the project's result will replace or improve. (1 page)
4. Teaming arrangement, description of roles, and list of key personnel (1 page)
5. Gantt chart or timeline showing monthly progress and quarterly milestones (1/2 page)
6. Budget estimate (sample format) given below (1/2 page)
7. Project Quad chart with no proprietary information, suitable for public distribution. Quad chart format is available from the PowerAmerica website. (1 page)

Concept Paper budget sample

	PowerAmerica funds	**Applicant Cost Match**
Organization 1:		
Personnel		
Equipment (>$5,000)		
Supplies & Materials		
Travel		
Indirect costs		
Subtotals per organization		
Organization 2: …		

Total project cost	

All Education and Workforce Development (Focus Area 5) Concept Papers must also include:
- Number of students involved and their role in the project
- Methods for disseminating educational materials developed.
- Industry impact if applicable.

D. Full Proposals

Proprietary, confidential, privileged, or trade secret information should be clearly marked in the header and footer of each page containing such information.

Documents must adhere to the following format:
- Page size – 81/2 x 11 inches
- Margins – 1 inch
- Spacing – single
- Font – Times New Roman 12 point

Full Proposals must include 4 separate files:

Items 1 - 6 as a single PDF file (15 pages Maximum, including cover)
Item 7 as a PowerPoint file
Item 8 as a macro-enabled Excel file
Item 9 as Word file

Full Proposals must include:
1. Cover page (same content as Concept Paper)
2. Technical project description (10 pages max; with similar content as Concept Papers, but more detailed)
3. Commercialization approach including target market, product or manufacturing insertion opportunity, deployment timeline, competition, barriers to market penetration, impact on U.S. competitiveness. Please include information about the expected market demand in terms of unit quantities in the one to five-year time frame, opportunities for system level cost reduction over comparable silicon solutions, and what products the project's result will replace or improve. Name potential customers for the product. (2 pages max)
4. Teaming arrangement, description of roles, and list of key personnel (1 page max)
5. Gantt chart or timeline should be provided showing monthly progress and at least one quarterly milestone.
6. Signed letter of commitment from the organization or university sponsored program office from each participating organization including a detailed description of the type and amount of cost share to be provided for the net 1:1 cost match.

7. Quad chart with no proprietary information, suitable for public distribution. Quad chart format available from PowerAmerica website. (https://www.poweramericainstitute.org/2017-call-for-projects/)
8. Budget and justification using the Department of Energy EERE – 335.1 form, available from the PowerAmerica website (https://www.poweramericainstitute.org/2017-call-for-projects/). Include travel to Raleigh, NC for two (2), 2-3 day meetings (PowerAmerica Member meeting and PowerAmerica WBG Workshop) for at least one representative from each funded organization and any student costs. Proposals with funding requests exceeding the PowerAmerica limits for any organization on the project will not be considered. Expenses for one attendee at one conference in the continental U.S. to present project results, or one attendee and one student for Universities are acceptable in the budget. Travel costs must be reasonable and consistent with the Federal Travel Regulations as well as the policies of the entity submitting the application.
9. A Statement of Project Objectives (SOPO) using the format available from the PowerAmerica website (https://www.poweramericainstitute.org/2017-call-for-projects/) is required for each organization of the project team. The SOPO is essentially a 2-3 page work plan that describes the specific project activities that will be performed and is divided into sub-tasks. It must list progress milestones, and deliverables. The SOPO is the contractual tracking tool the Institute will use for project management, so it should be prepared carefully.
    - Typical structure will include a project summary, followed by the sub-task summaries, followed by the associated milestones, and deliverables.
    - The number of milestones must be sufficient to measure the progress of the project each quarter and should include a minimum of one milestone per quarter that contain specific, measurable metrics related to the technology development. Multiple-organization projects are encouraged to merge related milestones of partner organizations with the proposing organization coordinating overall progress of the project.

All Foundry and Device Project Proposals (Focus Area 2) should specifically address:
1. Pricing expressed in $/A with comparison to current commercial retail pricing of Si and/or WBG component
2. Methods to qualify and validate the reliability of the devices
3. Ability to scale to volume production and to commercialize
4. Delivery of die and packaged devices to the Institute
5. Program management including number of wafers and wafer splits

University Team Members (Focus Area 2 - 4)
Universities conducting technical projects (Focus Area 2 - 4) are required to hire two undergraduate students. Student involvement should be described in the proposal. Graduate students and post-docs sponsored by the program are expected to be involved with the undergraduate students in research and to provide mentorship. Each undergraduate student is required to produce a project poster and to present in person at the PowerAmerica Annual Meeting (typically January or February) and/or the

PowerAmerica Summer Workshop (typically August). Student stipend/salary and travel to Raleigh, NC, should be included in the budget.

All Education and Workforce Development (Focus Area 5) Full Proposals must also include:

Number of students involved, and potential impact on industry
Methods and venues for disseminating education materials developed (if applicable)

E. Evaluation Criteria

PowerAmerica will assemble an external panel of experts from government, industry, and academia to review and score the proposals. An initial compliance review will be performed to ensure all application requirements and proposal contents have been submitted and that the applicant is eligible for selection. Compliant proposals will be reviewed according to the following evaluation criteria:

Technical Projects (Focus Areas 2 - 4)

1. **Technical Merit (Weight: 40%) -** The extent to which the project, if successfully carried out, will make a valuable contribution to the PowerAmerica mission. The project objectives are clearly stated, well-conceived, and technically feasible. The degree to which this project will provide valuable new tools, engineering processes, devices, or hardware/software/data to support adjacent Institute activities. The project addresses gaps in knowledge and technology to enable large-scale WBG semiconductor manufacturing. Project will materially advance the mission of the Institute to accelerate WBG semiconductor technology.

2. **Technical Approach (Weight: 20%) -** Adequacy and feasibility of the applicant's approach to achieving the stated objectives of the project. The extent to which the project plan, methods, analysis, and technology are properly developed, well integrated, and appropriate to the project objectives. Appropriateness, rationale, and completeness of the proposed SOPO. Degree to which the applicant has identified high risk challenges and presented reasonable mitigation strategies. Adequacy and appropriateness of the proposed schedule, staffing plan, and proposed travel.

3. **Technical and Management Capabilities (Weight: 20%) -** Likeliness that the proposed work can be accomplished within the proposed budget and performance period by the technical team, given their experience, expertise, past accomplishments, available resources, institutional commitment, and access to technologies. Clarity, completeness and appropriateness of the project plan and timeline. Clarity, logic, and effectiveness of the project organization, including sub awardees to successfully complete the project. Credentials, capabilities, experience of the key personnel. Adequacy and availability of personnel, facilities, and equipment to perform the proposed project.

4. **Commercialization Potential (Weight: 20%) -** The economic benefit to the U.S. and a U.S. company is clear; with U.S. manufacturing being advanced and with U.S. product innovation. A pathway to U.S. manufacturing is clearly stated with supply chain and other considerations (capital, equipment, facility, competition, other) discussed in some fashion. For manufacturers, pricing targets and volume estimates for 1,000 unit quantities should be stated. Preference will be given to proposals that generate or sustain U.S. manufacturing jobs. All proposals must address gaps in knowledge and technology to enable manufacturing that contributes to the PowerAmerica mission of realizing manufacturing job creation and energy savings through accelerated large-scale adoption of WBG semiconductor devices in power electronic systems.

Education and Workforce Development Projects (Focus Area 5)

1. **Technical and EWD Merit (Weight: 40%) -** The extent to which the project, if successfully carried out, will make a valuable contribution to PowerAmerica mission and make a unique and important impact in education and workforce development that promotes job creation in WBG power electronics manufacturing. Is the project proposal appropriate, and complete according to the SOPO? The project addresses gaps in knowledge and technology to enable large-scale WBG semiconductor manufacturing. Project will materially advance the mission of the Institute to advance WBG industry workforce needs.

2. **Relevance and Approaches to Innovation in Pedagogy (Weight: 30%)** - Are the educational objectives and pedagogical approaches clearly stated? Does the project have the potential to either augment or be easily integrated into established relevant curricula? Is it well designed, innovative, and does it have a substantial hands-on component (if applicable)? Can it be replicated and disseminated to other educational sites? Lastly, will this project proposal have an impact on helping to ensure a well-trained workforce for the emerging WBG power electronics industry?

3. **Subject Matter, Teaching, and Project Management Expertise (Weight: 30%) -** Does the project team possess the necessary subject matter expertise required of this project proposal? Does the teaching experience required to effectively create and deliver this subject matter exist within the project team or individual? Does the project team or individual have the necessary project management skills and track record required to complete this project proposal given the constraints of budget, time, personnel, other resources, and departmental and/or institutional commitment?

III. Types of Projects

For administrative and management purposes PowerAmerica is organized into five focus areas. This call for projects is soliciting proposals in focus areas 2, 3, 4 and 5 only.

Focus Area 1: Management, Operations, and Institute Sustainability
Focus Area 2: Foundry Operations and Devices
Focus Area 3: Power Module Packaging and Power Electronics Assembly Integration, Test and Reliability
Focus Area 4: Accelerating WBG Adoption for Power Electronics Applications
Focus Area 5: Education and Workforce Development

Throughout this document, the dollar amounts stated are the funds that will be provided by PowerAmerica. All projects require a minimum 1:1 net cost match.

A. Focus Area 2: Foundry Operations and Devices

Proposals with funding requests exceeding the PowerAmerica limits per organization will not be considered.

Applicants must commit to deliver engineering samples within 12 months for all FA 2 projects. Pricing information for 1,000 units is also required. Industry foundry projects must fabricate a minimum of five lots, with a minimum of six wafers per lot.

Topic 2.1 Silicon Carbide Open Foundry Infrastructure Advancement (Up to $750k)
The purpose of this topic is to support advancement of U.S.-based Silicon Carbide foundries that leverage existing 150 mm or 200 mm silicon device fabrication infrastructure, and are accessible to industry and universities. The goal is to establish infrastructure and full device process flows from wafer with epitaxy to qualified devices. Participants are expected to detail how an open foundry model suitable for discrete power devices will be created and how the foundry can be made accessible to all users. This includes developing manufacturable unit processes, implementation of process development kits (PDK), ability to maintain confidentiality between users, and processes, and quality controls that meet or exceed industry standards. The foundry should leverage existing equipment, ideally have device production running at nearly full capacity, be able to attract customers, and manage a multiple user foundry. The foundry should have the capability to run small wafer lots to support research projects and open foundry process development at reasonable costs. The foundry is expected to exploit existing manufacturing economies of scale to reduce SiC manufacturing cost. The foundry must outline how its pricing will be competitive with respect to that of worldwide SiC open foundries to ensure viability beyond the PowerAmerica funding period.

It is expected that the foundry will have significant other commercial business (at least 10,000 wafers/month) and most of the necessary equipment to develop a process along with PDK and sample designs for silicon carbide power devices. A capital equipment plan should be presented showing the foundry's commitment to long-term SiC foundry operations. This plan can include assumptions of using PowerAmerica-related fabrication and projects to offset equipment costs (i.e. some expectations of fee for use by PowerAmerica members and outside members, or internal use should be included to demonstrate viability of the foundry over a 5-year time period). Proposals of SiC power device specific foundry equipment that facilitates high volume manufacturing by eliminating well known processing bottlenecks will also be considered.

Topic 2.2 Gallium Nitride Open Lateral Power GaN Foundry Infrastructure Development (Up to $1M)

The purpose of this topic is to support the development of a U.S.-based Gallium Nitride foundry that leverages existing 150 mm or 200 mm silicon device fabrication infrastructure, or GaN RF device processing lines, or GaN LED processing lines, and will be accessible to industry and universities. The goal is to build the infrastructure to demonstrate the capability to run full device process flows from epitaxy to qualified devices without the wafer leaving the foundry for any unit steps. Participants are expected to detail how an open foundry model suitable for discrete and/or integrated power devices will be created and how the foundry can be made accessible to all users. This includes implementation of process development kits (PDK), ability to maintain confidentiality between users, and process and quality controls that meet or exceed industry standards. The foundry should be able to leverage existing equipment, ideally having previously demonstrated RF, LED, or power devices, and the ability to attract partners and manage a multiple user foundry. The foundry should have the capability to run small wafer lots to support university work and open foundry process development at reasonable costs. The ability to support a fully open baseline process for 650 V GaN lateral power devices, and an open process for integrated GaN devices is preferred. The foundry is expected to be able to scale to high volumes, or have demonstrated ability to transfer processes to larger volume fabrication facilities. The foundry must outline how its pricing will be competitive with respect to that of worldwide GaN open foundries to ensure viability beyond the PowerAmerica funding period.

It is expected that the foundry will have significant other commercial business (at least 10,000 wafers/month) and most of the necessary equipment to develop a process along with PDK and sample designs for lateral GaN power devices. The foundry is expected to exploit existing high volume manufacturing economies of scale to reduce lateral GaN manufacturing costs. A capital equipment plan should be presented showing the foundry's commitment to long-term GaN foundry operations. This plan can include assumptions of using PowerAmerica-related activities and projects to offset equipment costs (i.e. some expectations of fee for use by PowerAmerica members and outside members, or internal use should be included to demonstrate viability of the foundry over a 5-year time period). Proposals of lateral GaN power specific foundry equipment that facilitate high volume manufacturing by eliminating well known processing bottlenecks will also be considered.

Topic 2.3 Next Generation Silicon Carbide Devices (Up to $600K for Industry and up to an additional $300K each for Universities and National labs teaming with industry)

Industrial device proposals should primarily be directed at implementing or advancing device flows to produce cost effective devices at volume within captive or open foundries. Examples of device improvements include improvements in yield at larger die size, better edge termination, specific on-resistance reduction, improved integration of diodes, and improved short-circuit and avalanche-energy safe-operating area. As SiC MOSFETs with blocking voltage in the range of 900-3,200 V are commercially available, the majority of industrial proposals are expected to focus on fabrication and qualification of devices with a blocking voltage rating in the range of 3,200 V to 15,000 V. 650 V through 900 V MOSFETs with a very low specific on-state resistance (using planar or trench configurations) will also be considered. Devices with suitable metallization on top and bottom to facilitate double-sided packaging will also be considered.

- Execution of device proposals in an open foundry is preferred, but can be performed in a vertical foundry assuming that the task leads to the qualification and release of devices/modules on an accelerated schedule with aggressive price targets.
- Projects with aggressive price targets and sufficient market justification are encouraged, especially if tied to the production of an end user product.
- All projects should result in release of engineering samples or a qualified product with 1,000 unit volume pricing, or improvements in an existing product's market competitiveness.
- Proposals should include a deliverable to PowerAmerica's device bank for members to use for application development.
- Proposals for device manufacturing should include fabrication of at least five lots.

Industry proposals for device manufacturing are preferred, but one or more universities or national labs may team with industry to develop an open process or to characterize reliability or Safe Operating Area for example.

Topic 2.4 Gallium Nitride Power Devices
(Up to $500K for Industry, and up to an additional $250K each for Universities and National labs teaming with industry)

Industrial device proposals should choose an appropriate target voltage that is commercially competitive. Typically, this has been 650 V or higher, but may be adjusted if suitable commercial justification can be provided. Industrial members are encouraged to use or assist in the development of the baseline open process, but it is recognized that for competitive devices industry device proposals may contain proprietary unit steps even when using the open foundry.

Execution of GaN device proposals in an open U.S. foundry is preferred, but can be performed in a closed or vertical industrial foundry located in the U.S. assuming the task leads to the qualification and release of devices/modules on an accelerated schedule with aggressive price targets. It is assumed that 100 mm foundries are not capable of meeting the pricing targets, and use of 100 mm foundry will require a strong commercialization planning justification.

Universities are expected to use the open foundry and to team with industry to provide potential pathways for commercialization.

B. Focus Area 3: Power Module Packaging and Power Electronics Assembly Integration, Test & Reliability

Proposals with funding requests exceeding the PowerAmerica limits per organization will not be considered.

Topic 3.1 Power Module Packaging (Up to $500K for Industry, and up to an additional $250K each for Universities and National labs teaming with industry)

Sub-Topic 3.1a High Performance Power Module Packaging, Gate-Drive Boards, and Busbar Assemblies that exploit the positive attributes of WBG devices with low thermal impedance, low inductance, and high temperature capability are needed for 3.3 -10 kV devices. Proposals are also encouraged for module evaluation kit development (including busbar assembly and gate drive) to promote insertion of newly developed high voltage modules (>6.5 kV) in MV (medium voltage) applications. Power module packaging proposals that address engine fluid cooling, and double-sided cooling are sought. Power module packaging proposals that address specific high-volume segments of the WBG power application market will be considered; a compelling case for high anticipated market volume must be made. Proposals for discrete packages are discouraged. Power module packaging proposals should include a roadmap for anticipated pricing, with the expectation that the proposal would accelerate the announcement and release of new products. Open packaging houses that are accessible to and accommodate the module needs of the WBG device community are sought. Packaging houses with existing volume Si, SiC or GaN packaging lines that exploit economies of scale are encouraged to apply. It is expected that proposals for packaging will contribute to the Institute device bank to stimulate accessibility and availability of modules for academia and industry innovation. Power module 100-unit budgetary pricing should accompany product release. Universities, national labs, and small companies must partner with large industrial packaging houses to facilitate a transition to manufacturing.

Topic 3.2: Reliability and Testing Services for SiC and GaN (up to $250K for Industry, and up to $200K for University and National Lab Projects)

The intent of the reliability and testing services task is to provide independent assessment of reliability to validate industry reliability measurements and give the end user community the appropriate information to make decisions about adopting wide bandgap semiconductors. The reliability and testing services are intended to independently assess the performance of commercially available devices, and to perform assessments of engineering device samples. The reliability and test data provide feedback on device ruggedness and can assist in optimizing the manufacturing processes. Applicants must have procedures in place to maintain and control proprietary information and samples that are not yet commercially released. Round Robin-type studies are encouraged, assuming appropriate control of proprietary information can be assured.

Sub-Topic 3.2a High Voltage SiC Device Reliability and Lifetime Uniformity proposals are sought that contribute to understanding the formation of basal plane dislocations and other defects due to room temperature ion implantation and subsequent anneal. Implementing room temperature implantations at high yields is critical for manufacturing cost reduction. Uniformity of excess carrier lifetime is also critical to high voltage device manufacturability. Wafer mapping at various device fabrication stages should be performed and correlated with device performance to understand the impact of underlying defects.

Sub-Topic 3.2b Avalanche Ruggedness and Short-circuit Capability of SiC and GaN Transistors is focused on inductive avalanche testing of SiC and GaN transistors at room and elevated temperatures as well as the short-circuit capability. Power converter circuits are often exposed to transients due to line or load disturbances. Devices that can safely dissipate excessive energy during avalanche breakdown are desirable for reliable operation. Many silicon power MOSFETs offer avalanche capability. However, silicon devices' ability to absorb avalanche energy diminishes rapidly with increased junction temperature. Wide bandgap semiconductor devices offer opportunity to dissipate significant avalanche energy at high operating junction temperatures. Devices that have short-circuit withstand time long enough to enable detection and shutdown without damage are also required in many applications. Proposals are sought that measure single and repetitive inductive avalanche energy and short-circuit withstand time of commercially available wide bandgap power devices and engineering device samples at room and elevated junction temperatures typical for their operating conditions. Proposals should also include development of measurements for repetitive hard switching of commercially available wide bandgap power devices and engineering device samples at room and elevated junction temperatures under typical and accelerated biasing operating conditions.

C. Focus Area 4: Accelerating WBG Adoption for Power Electronics Applications

Proposals with funding requests exceeding the PowerAmerica limits for each organization will not be considered.

(For projects using commercially available devices, funding up to $500K for Industry, and up to an additional $250K for each University and National lab teaming with industry. For projects using high voltage engineering samples, funding up to $600K for Industry, and up to an additional $300K for each University and National lab teaming with industry.)

The Institute is seeking power electronics converters and inverters to further advance wide bandgap power semiconductor applications, which can potentially have large impacts on energy efficiency, weight and volume reductions, and can be widely deployed. Industry technical specifications should meet applicable standards; including competitive analysis, cost model and commercial volume targets developed in cooperation with manufacturing partners. Reference designs should be provided to support wide adoption and development of next generation of products. Teaming between universities and industry is particularly encouraged in this focus area. With input from industry and academia, we have prioritized projects for the following application areas:

Topic 4.1 Transportation and Energy Constrained Mobile Systems
This category includes ground and marine vehicles, hybrid cars, heavy-duty vehicles, traction, aeronautics and unmanned systems. Power electronics are principally needed to achieve fuel savings through efficient electrification of propulsion and/or other on-vehicle power systems. However, it is increasingly important to also be able to export electrical power to subsystems or to supply power to external systems. Fast charging, ability to receive or send power to the grid, or to connect to power storage systems are increasingly important. Wide bandgap power electronics provides significant system-level advantages in enabling electrification of transportation and mobile systems due to their reduced size and weight, and capability to operate at higher temperature, speed and voltages. Projects addressing inverters/converters with power levels above 200 kW and/or device blocking voltages above 1,200 V are of particular interest.

Sub-Topic 4.1a EV Fast Charger
The Electric Vehicles Initiative's (EVI) goal is to have over 20 million electric cars on the road by 2020. Approximately 27,700 fast chargers were available globally in 2015 and the predictions are that the number of fast chargers would increase tenfold by 2020 and by a factor of 80 to 120 by 2030. The efficiency of conventional fast chargers does not exceed 93% with typically large overall size and weight, and high installation cost. The goal is to develop an efficient EV fast charger prototype with reduced size and weight. Use of SiC devices with 3.3 kV or higher blocking voltage is preferred. The fast charger should feature 12.47 kV three-phase AC input, and 350 -1,000 V DC output and should meet or exceed the following specifications: 350 kW output at 1,000 V, 98% peak efficiency, power density exceeding 1.5 kW/dm^3, and current THD < 2% at full load. Design should be ruggedized for commercial installation, with all necessary circuit protection.

Sub-Topic 4.1b SiC Inverter for Heavy Duty Vehicles (200 kW, 1,050 V DC Bus)
Project should include advancement and heavy-duty vehicle level testing of the liquid cooled SiC inverter with power density > 20 kW/dm^3. For sustained fuel economy gains, the 200 kW SiC inverter should offer efficiency greater than 97% when tested with 95 °C – 115 °C coolant. Impacts of the high switching frequency of SiC devices should be quantified for (a) inverter DC bus capacitor size reduction, (b) improvement in the bandwidth of electric drive-train control system used in heavy-duty vehicle, and (c) reduction of the electric motor losses. Proposals should include approaches to reduce assembly cost and improve vehicle integration. Successful deployment and testing of the 200 kW SiC inverter in a heavy-duty vehicle application should demonstrate system level cost and performance tradeoffs of the WBG power electronics technology. To accelerate adoption of this technology in heavy-duty applications, the proposal must quantify the following:

1. Expected vehicle fuel economy offered by WBG power electronics.
2. Expected power density of WBG power electronics at elevated temperature of inverter coolant.
3. Simplification of vehicle system design resulting from the elimination of the dedicated inverter cooling loop.
4. WBG System cost savings with respect to silicon based power electronics.

Sub-Topic 4.1c SiC Wireless Charger for Light or Heavy Duty Vehicles The electric vehicle charger market is expected to grow significantly over the years as new electric cars come to market. Wireless chargers capture only 3.1% of the market at present and they are forecast to grow at a CAGR of 31.14% during the period 2016-2022. [1]The institute is seeking proposals to develop SiC based wireless charging system for light or heavy duty vehicle applications that meet the newly released SAE TIR J2954 standard. The wireless chargers need to meet the following specifications: 240 VAC input and 22 kW (WPT 4) for light vehicle application, 480Vac input and 50kW-250kW (WPT 4) for heavy duty vehicle application, 400VDC-1000VDC output, operating frequency is 85 kHz (81.39 - 90 kHz), max efficiency > 95% under aligned conditions excluding AC/DC PFC stage. The charging technology shall be ready for a vehicle integration demonstration. It must meet safety and EMC/EMF standards. The power transfer flexibility as a function of air gap spacing and horizontal alignment shall be demonstrated over a reasonable range, which should be a valid representation of real world application.

Sub-Topic 4.1d Automotive DC-DC Converter
In order to provide different low voltage rails in electric vehicles, it is desired to develop highly efficient, compact and light-weight DC-DC converters for automotive application. The DC-DC converter is connected between the high voltage battery pack for the power train and low voltage battery for auxiliary electronic components. The input voltage of the DC-DC converter is 400V minimum and it can be as high as 1,200V-1,500V for heavy duty vehicle application. The output voltage is 48V or 28V or other common low voltage levels. Depending on the specific application, it may make sense to have multiple output voltage levels to drive various components directly, without another stage of downstream DC-DC conversion.

[1] "Global Electric Vehicle Charger market - By Type, End Use, Regions - Market Size, Demand Forecasts, Industry Trends and Updates (2015-2022)," Research and Markets, 2017.

Topic 4.2 Renewable Energy Applications and Power Electronics for Energy Exploration
The emphasis of this category is on increasing the efficiency, reliability, power density and portability of inverters for solar, wind, geothermal and other renewable energy systems while decreasing the size and weight. Efficiency impacts the overall profitability of the systems, but size, weight and reliability significantly impact the installation and maintenance costs of the systems. Energy exploration is resulting in significant innovation for down borehole electronics, and for motors and generators used to drive equipment including subsea. These energy exploration applications pose very demanding environmental conditions on the power electronics and require delivery of power over long distances. Proposals should include cost models for energy savings and cost of ownership and comparison of performance advantages of wide bandgap power electronics. Proposals are requested for:

Sub-Topic 4.2a Medium-Voltage Motor Drives for Energy Exploration
Demonstrate a compact medium-voltage variable-speed motor-drive inverter/convert system in the lab at >100 kW that is scalable to down borehole or off-shore sub-sea energy exploration applications. Proposal should include a comparison of performance advantages of wide-bandgap power electronics compared to silicon electronics and hydraulic approaches. Proposers should team with energy exploration equipment suppliers to address from, fit and function requirements.

Sub-Topic 4.2b Transformerless Medium Voltage Central PV Inverter
Demonstrate 200 to 500 kW transformer-less (Direct Grid Connected) photovoltaic inverter block paired with high-gain boost converters using 900 – 1,500 V DC input. Inverter transformers provide convenient isolation and step-up of the output voltage. However, medium voltage inverter insulation requirements lead to substantially higher leakage inductance, increasing switching losses[2] and limiting the transformer power transfer capability at higher switching frequencies used by WBG devices. Progress in high-gain boost converters[3,4,5,6] demonstrates potential for reducing cost and size of passive components of central PV inverters. Overall CEC efficiency > 97.5%, exceeding 2 kW/kg and inverter output connected directly to the medium voltage distribution system at 13.8 kV AC are desirable. Reactive power support[7], ground fault[8] and line transient protections[9] are required.

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[2] Basu, Kaushik, et al. "A Single-Stage Solid-State Transformer for PWM AC Drive With Source-Based Commutation of Leakage Energy." IEEE Transactions on Power Electronics 30.3 (2015): 1734-1746.
[3] Hernandez, Adan F., and Gert W. Bruning. "High frequency inverter with power-line-controlled frequency modulation." U.S. Patent No. 5,404,082. 4 Apr. 1995.
[4] Rosas-Caro, Julio Cesar, et al. "DC-DC multiplier boost converter with resonant switching." Electric Power Systems Research 119 (2015): 83-90.vd
[5] Rosas-Caro, Julio Cesar, et al. "A transformer-less high-gain boost converter with input current ripple cancelation at a selectable duty cycle." IEEE Transactions on Industrial Electronics 60.10 (2013): 4492-4499.
[6] Gonzalez-Hernandez, Jose Genaro, et al. "Bootstrap cascaded multilevel converter." IEICE Electronics Express 11.17 (2014): 20140561-20140561.
[7] Abraham Ellis, et al. "Reactive Power Interconnection Requirements for PV and Wind Plants – Recommendations to NERC," SANDIA REPORT SAND2012-1098, February 2012.
[8] Solar America Board of Codes and Standards: Ground-Fault Detection Blind Spot. http://www.solarabcs.org/about/publications/reports/blindspot/
[9] Rich Seguin, et al. "High-Penetration PV Integration Handbook for Distribution Engineers," NREL Technical Report NREL/TP-5D00-63114, January 2016.

Sub-Topic 4.2c 1 MW Inverters for Wind Applications
A Permanent Magnet Generator (PMG) medium voltage wind inverter with +/- 2.5 kV input (5 kV differential) with bidirectional capability to support multiple speed range configurations,[10] reactive power and primary frequency response is desired.[11]

Sub-Topic 4.2d 200 to 500 kW Inverter Blocks for Medium and Large Wind Applications
Inverters for doubly fed induction generators (DFIG) and gearless direct drive machines for wind turbines. Power inverter blocks utilizing wide bandgap power semiconductor devices could allow operation at higher voltages, lowering currents in the windings and reducing size and cost of the turbine.[12,13] High efficiency of the inverter can reduce heat dissipation that can be handled by smaller and lower cooling systems. The power inverter blocks should have the following characteristics: 200 to 500 kW, > 96% efficiency, 1,200 V or 1,700 V power transistors, designed for high reliability. The machine voltage should be higher than 690 V AC.

Sub-Topic 4.2e Medium Voltage DC-DC Converter for Wind Applications
The typical variable output voltage of the 3.3 kV AC medium voltage wind turbine generator is rectified to a DC voltage by a diode bridge followed by a boost converter which converts the unregulated DC to a higher regulated DC bus voltage (5.5 kV DC). The medium voltage DC-DC converter with high frequency isolation transformer is used to step up the 5.5kV bus voltage and connect it to a higher voltage DC bus (55kVDC). The 55 kV DC bus connects to the High-Voltage Direct Current (HVDC) transmission line through another conversion stage. The goal of this project is to eliminate bulky and expensive line transformers and develop reliable, efficient, and cost effective SiC based Medium Voltage DC-DC converters for wind application.

Topic 4.3 Energy Efficiency for Communications, Digital Systems, and Data Centers
The demand for energy used in communications and digital systems is growing rapidly. The faster switching speed of WBG power electronics, their ability to perform at higher junction temperatures and the accompanying reduction in size of passive components and heat sinks, suggest that WBG semiconductors will play a major role in mitigating the growing energy consumption of data centers, power supplies for cellular RF communications, power supplies and adapters for consumer electronics including computers and laptops, enterprise equipment, cell phone wireless charging, and LED driver electronics. Proposals are requested for:

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[10] Erdman, William, and Jonathan Keller. The DOE Next-Generation Drivetrain for Wind Turbine Applications: Gearbox, Generator, and Advanced Si/SiC Hybrid Inverter System: Preprint. No. NREL/CP-5000-66562. NREL (National Renewable Energy Laboratory (NREL), Golden, CO (United States)), 2016.
[11] Gevorgian, Vahan, Yingchen Zhang, and Erik Ela. "Investigating the impacts of wind generation participation in interconnection frequency response." IEEE transactions on Sustainable Energy 6.3 (2015): 1004-1012.
[12] Zhang, Hui, and Leon M. Tolbert. "Efficiency impact of silicon carbide power electronics for modern wind turbine full scale frequency converter." Industrial Electronics, IEEE Transactions on 58.1 (2011): 21-28.
[13] Blaabjerg, Frede, and Ke Ma. "Future on power electronics for wind turbine systems." Emerging and Selected Topics in Power Electronics, IEEE Journal of 1.3 (2013): 139-152.

Sub-Topic 4.3a Miniaturized Laptop Adapter with greater than 25 W/in^3 power density and high efficiency at 25% and 50% loads. It should meet all the commercial standards and regulations and should be developed for commercialization at end of the project cycle.

Sub-Topic 4.3b Open Source Design of a Programmable WBG Power Supply
Integrated onto 4 level printed circuit board, area less than 4 x 2 inches with greater than 98% efficiency, with 120/240V AC input, and +/-15V, +/-5V, +/-3.3V DC outputs meeting EMI and EMC standards.

Sub-Topic 4.3c High Bandwidth Power Supply for RF Communication Systems
Also known as envelope tracking power supplies. The growth of cellular communications and studies suggest that there is a large market and potentially significant energy savings to be obtained through the use of WBG enabled RF power supplies. One possible solution is a high bandwidth, high efficiency DC-DC converter with a minimum bandwidth of > 20 MHz (possibly extendable to a target of 80-100 MHz) while at the same time obtaining efficiencies > 90 %. The proposal should describe the required saturation output power needed for the chosen application, but is anticipated to be greater than 200 W.

Sub-Topic 4.3d High Efficiency GaN-based Mobile Device Wireless Chargers
Most wireless chargers have a separate AC adapter. An integrated unit with AC to DC efficiency above 80%[14], 10W output power and power density exceeding 3 W/in^3 is desirable. It must comply with FCC Part 15 and/or Part 18.[15] It shall meet one of the latest wireless power standards: Airfuel Alliance (A4WP and PMA) or Wireless Power Consortium (WPC).

Sub-Topic 4.3e High Efficiency SiC or GaN-based LED Drivers
Demonstrate an AC/DC two stage LED driver solution for LED lighting for fixture applications targeting the middle power, high-end architectural fixture market. Universal input voltage varies between 120 V and 277 V. Input power level should be around 50 W which translates to 5,000 lumens output at the fixture level. Performance specifications include: THD<10%, PF>0.9, Efficiency>94%, FCC Class B EMI compliant. Power devices can be GaN or SiC or both. It must have two output channels which can drive two LED strings independently. The string voltage is 50 V or less. The driver is deep-dimming capable with the output current varying between 1 mA to 1,000 mA with a resolution of 1 mA. Output current ripple and transient should be minimized to avoid any flicker or flashing. Switching frequency should be in the range of several hundred kHz to MHz level to reduce driver size to fit into compact fixtures.

Sub-Topic 4.3f High Fidelity GaN-based Audio amplifier

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[14] John Perzow, "Measuring Wireless Charging Efficiency in the Real World," Battery Power 2015, Denver, Colorado.
[15] RF exposure and compliance information is in an attachment to the publication number 680106 at FCC Office of Engineering and Technology.

According to Research and Markets, the Class D audio amplifier market is expected to be worth $2.76 billion by 2022, growing at a CAGR of 17.4% between 2016 and 2022. [16] Class D audio amplifier distortion requirements, THD+N (Total Harmonic Distortion plus noise), Inter-Modulation (IM), and T-IMD (Transient Inter-modulation Distortion), are all directly tied to the characteristics of the switching transistors used in the power stage such as switching speed, stored charge, reverse recovery (Qrr). [17]Owing to its lower conduction losses, faster switching speed and zero reverse recovery losses, GaN FETs allow amplifier designers to increase PWM switching frequencies, reduce dead-time, set higher bandwidth and drastically reduce feedback. Demonstrate a class D amplifier solution with sound quality that surpasses MOSFET based Class D and traditional Class A or AB linear amplifiers. Output power of 200W- 400W, THD+N (v.s. power) < 0.05% THD+N, (v.s. frequency) < 0.02%, Efficiency > 96% is desired.

Sub-Topic 4.3g Direct 48V to sub-1V Point-of-Load (PoL) DC-DC Module

Compared to conventional 2 stage 48V to 1V power systems (with intermediate 12 V DC bus), the direct 48 V to 1V power architecture dramatically improves efficiency and power density with simpler implementation and lower cost. Demonstrate a single stage DC-DC converter prototype to drive high power CPUs, GPUs and ASICs with 48V nominal input voltage, 1V or below output, Iout > 200A, frequency > 1 MHz, power density > 1000W/inch^3, efficiency > 95%, board level demonstration is expected to prove the designed converter meets the latest Intel VRM (Voltage regulator module) specifications.

Sub-Topic 4.3h 480 V AC to 400 V DC Front End Rectifier for Data Center Application

Data centers accounted for 2.2% of the total U.S. energy usage in 2012. Power architecture innovation at the system level combined with the advent of WBG power devices at module level will dramatically increase power delivery efficiency and simplify the data center power system design. Compared to traditional AC-powered data centers, DC-powered data centers have a much simpler power architecture, which has potential to provide lower energy conversion losses, higher reliability and smaller equipment footprints for power conversion. DC distribution provides advantages of higher efficiency, added flexibility, and lower capital cost over AC distribution.[18] Demonstrate a three-phase AC rectifier prototype with three phase AC input (380VAC-480VAC) and the output voltage at 400V nominal (290 V - 400 V DC). To fully exploit the advantages of WBG devices, innovative topologies should be employed to achieve efficiency higher than 99% and higher power density than that of the Si counterpart. The rectifier shall meet FCC part 15 class B for both conducted and radiated EMI. The input power is 10 - 20 kW and scalable to over 100 kW by stacking multiple modules.

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[16] "Class D Audio Amplifier Market by Type (Mono Channel, 2-Channel, 4-Channel, 6-Channel), Device (Handset, Television, Home Entertainment Systems, Multimedia Sound Case, In-Car Audio), End-User Industry, and Geography - Global Forecast to 2022," 2016. https://www.researchandmarkets.com/reports/3876686/class-d-audio-amplifier-market-by-type-mono#pos-1

[17] Maria Guerra, "Can Class-D Amplifier Audio Performance Get Any Better?," in Electronic Design, 2016

[18] Annabelle Pratt, Pavan Kumar, et al., "Evaluation of 400V DC Distribution in Telco and Data Centers to Improve Energy Efficiency," in Telecommunications Energy Conference, INTELEC, 2007

Sub-Topic 4.3i MV AC to 400Vdc AC-DC Rectifier
To further improve the DC data center efficiency, the MV (4.16 kV or 13.8 kV) line frequency transformer and UPS can be replaced by a single stage AC-DC rectifier with MV AC input and 400 V DC output. The energy storage (battery) is tied to the 400V DC bus through another DC-DC converter. The AC/DC rectifier prototype should have the following specifications: 4.16 kV (or 13.8 kV) input, 400V output, >20kW power, modularized and scalable to higher power, > 97% efficiency, power stage based on high voltage 10 kV/15 kV SiC MOSFETs or low voltage 1.2 kV/1.7 kV MOSFETs depending on topology.

Topic 4.4 Enabling Subsystems for Medium Voltage Systems and Energy Efficient Motor Drives
There is significant Institute interest in potential applications of 3.3 kV - 15 kV wide bandgap semiconductors. There are several options to consider in the design of multi-level High-Voltage systems where reliability is the critical performance parameter. For example, 3.3 kV SiC devices are more mature and align with a common voltage used for Si IGBTs, whereas systems built with higher voltage 6.5 kV - 15 kV SiC devices result in a lower part count and control simplification. The development of 3.3 kV and 10 kV power modules, and their availability in sufficient quantity and quality to be field tested in systems is important in addressing this trade-off. Furthermore, being able to control and monitor the building blocks is important. Proposals are requested for:

Sub-Topic 4.4a Medium-Voltage Asynchronous Microgrid Power Conditioning System (Microgrid PCS) to connect, disconnect, and asynchronously flow power from microgrids to the larger grid. The Institute seeks to develop an Asynchronous Microgrid Power Conditioning System which can be modular MVAC (13.8 kV AC) to MVAC (4,160 V AC and 13.8 kV AC) power conditioning system blocks (PCSB) that can be used for grid interconnection of Megawatt-scale flow control microgrids (asynchronous MVAC microgrids). The PCSBs shall have bi-directional power flow capability and be scalable so that they can be used for a broad range of flow control microgrids of different scale (100 kW to multi-MW) including microgrids that have net generation or net load power flow at the point of connection to the larger grid. This bi-directional power flow solution should be 60 Hz transformer-less. This modular approach is intended to result in higher-volume, lower-cost power electronics building blocks that service many applications at standard voltages: 4,160 V AC and 13.8 kV AC. This Microgrid PCS solution should enable multi-port integration of renewable energy sources to the main grid. The overall efficiency of the Microgrid PCS should be > 98% and with low/partial load (<30% loading) efficiency > 95%.

The Microgrid PCS solution can be implemented with 3.3 kV to 10 kV SiC MOSFET modules. The modular converters shall utilize high-voltage, high frequency (>10 kHz) power electronics to reduce cost, size (< 4 m^3/MW), footprint of < 3 m^2/MW, volume of >15-20 kW/L, and weight (> 15 kW/kg) and to provide the bandwidth (voltage control BW > 300 Hz and current control BW > 1 kHz) needed for both the grid-facing and microgrid facing functions required by interconnection standards plus functions required for a wide range of generator, storage and load applications. This project is required to demonstrate a Microgrid PCS connector from 13.8 kV MVAC to MVAC (4,160 V AC or

13.8 kV AC) system in the lab at a power rating of at least 100 kW. Proposers should team with utilities to address architecture, fault protection, and other system level requirements.

Sub-Topic 4.4b MV Motor Drive Inverter
Demonstrate a >200 kW inverter for motor drive applications with a > 3 kV DC bus using > 3.3 kV SiC switches, with a fundamental frequency > 500 Hz, a switching frequency > 5 kHz, high power density, low EMI, a THD <5%, low dv/dt on motor windings, low common mode voltage on motor bearings and efficiency > 96%. Four quadrant operation is required. The institute also has interest in integration and testing of high-speed medium-voltage SiC motor drives with a high-speed motor.

Topic 4.5 Advanced Power Grid Continuity, Power Quality, and Fault Protection

Continued addition of renewable energy sources such as solar and wind, the increased use of natural gas for electrical energy generation[19,20] and the shutdown of one-third of coal-fired power plants since 2011 increase the need for power electronics systems that can provide continuity of power, control reactive power and provide circuit protection. The inherent variability of solar and wind generation create rapid power generation ramps,[21,22] which require a flexible and adaptable power grid. Today transformers equipped with On-Load Tap Changers (OLTC) allow voltage adjustment and automatic voltage control.[23] However, the high variability of renewable generation can increase the frequency of activation of mechanical OLTC, potentially reducing their useful lifespan. Power transformers and switchgear equipped with fractional power rated converters can provide improved functionality with much more frequent switching ability and continuous adjustment. Voltage dependent reactive power provision and electronic OLTC can provide autonomous voltage control necessary for high penetration of renewable generation.[24] Adaptable power grid spans a wide range of power levels, but many such systems can benefit from the introduction of wide bandgap semiconductors, especially in terms of size, in the reduction in the number of power electronics switching devices needed, and in the increase in equipment durability under frequent or repeated switching conditions. Projects that address significant markets such as medium voltage (6.5 kV and above) uninterruptable power supplies, and medium voltage, high-current (>100 amp) solid-state circuit breakers, interrupters, reclosers, compensators and other automated switchgear are of interest. Since there is an anticipated market for these applications the proposal should outline approaches to market including a risk assessment of competition from silicon and mechanical switching approaches.

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[19] "Scheduled 2015 capacity additions mostly wind and natural gas; retirements mostly coal," EIA Today in Energy, April 2015. http://www.eia.gov/todayinenergy/detail.cfm?id=20292#

[20] "Solar, natural gas, wind make up most 2016 generation additions," EIA Today in Energy, March 1, 2016.

[21] "What the duck curve tells us about managing a green grid," California ISO. http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

[22] Fowlie, Meredith "The Duck has Landed," Energy Institute at Haas blog, UC Berkeley, May 2, 2016.

[23] Corsi, Sandro. Voltage control and protection in electrical power systems: from system components to wide-area control. Springer, 2015.

[24] Stetz, Thomas. Autonomous Voltage Control Strategies in Distribution Grids with Photovoltaic Systems: Technical and Economic Assessment. Vol. 1. Kassel University Press GmbH, 2014.

At higher voltages, approaches using wide bandgap devices for fractional power FACTS (Flexible Alternating Current Transmission Systems), including SVAC (Static VAR Compensation) for power transmission are of interest. In these applications, demonstration of circuit topology and reduction of the number of switching devices used, and pathways to performing field tests should be identified. To keep the high-voltage component costs down, a modular approach at ½ MW power levels could be considered.

Sub-Topic 4.5a Flexible Sub-transmission Power Transformer

A 138/115 kV to 34.5 kV, 40 MVA or similar sub-transmission power transformer can be equipped with a fractional power converter to augment OLTC. The converter control range should allow voltage change of +/-6%, phase of +/-4 degrees, while power losses are less than 0.3% of the transformer rated power. Utility participation is encouraged.

Sub-Topic 4.5b Flexible Phase Angle Regulator (Phase Shifting Transformer)

Phase Angle Regulators (PARs) are commonly used to control power flow in the electric grid and have a regulation range typically from +/-20 to +/-60 degrees, depending on the regulator size. A 550 MVA unit can typically provide 50 degrees of regulation in 32 steps. The available number of the tap changes is about 1 million operations or about 70 per day over 40-year useful life. The accuracy of the power flow is limited by the number of steps and is about 3 to 4% of nominal power rating. PAR augmented with a fractional power converter providing an additional phase regulation range, greater than the tap changer step, would reduce frequency of tap changes and allow much more precise control of the power flow. This concept has been demonstrated at the distribution voltage level. Silicon carbide devices can enable application of this technology at transmission voltages. Demonstration of a power converter suitable for retrofitting or augmenting a 69 kV (or higher rated) Phase Angle Regulator and testing of the combined unit is required. Utility participation is encouraged.

D. Focus Area 5: Education and Workforce Development

Proposals with funding requests exceeding the PowerAmerica limits will not be considered.

The mission of the Education and Workforce Development (EWD) focus area is to assist educators and trainers from academia and industry in building *career pathways* for students and professionals to enter the next WBG generation power electronics industry. The PowerAmerica community has a unique opportunity to excite young people primarily in upper undergraduate and graduate university levels about the meaningful impact that this technology will have at the individual, societal, and environmental levels and the critical role young people can play in advancing this technology.

The EWD focus area is open to all PowerAmerica members and all university faculty and their research teams (i.e. engineering, science, instructional design, etc.) college instructors, nonprofits, startups, as well as established businesses interested in training the workforce needed by the emerging WBG power electronics industry. The purpose of FA5 is to address gaps in workforce education to meet the rapid transition from silicon-based power electronics to WBG-based power electronics, and to expand power electronics systems to the new transformative higher-voltage and higher-frequency applications enabled by WGB technology. Education topics focus on upper-level undergraduate students and graduate students working in WBG power electronics, and may also include workforce development for professionals through continuing education. EWD activities include the following and others identified by this RFI:

Submitted project proposals must target age and skill appropriate levels. Areas of particular pedagogical interest are:

- Short courses–1/2 day to 1 day in length. Short WBG topic-targeted modules that are stand alone or that can be used to augment existing courses at all university levels
- Instructional videos and WBG informational videos
- Course and laboratory curriculum development, textbooks, instructional material development etc. Leveraging, expanding, and adding power WBG content to existing power electronics education programs will be considered.
- Innovative outreach to other educational areas to build the ecosystem needed to quantify and leverage the transformative potential of WBG power electronics. For example, partnerships with business schools to conduct impact studies of WBG applications or ideas for other similar partnerships are sought.
- Exposing entry-level graduate students to international WBG power electronics conferences (ISPSD, etc.) and internships that inspire them to seek graduate education and career opportunities in WBG power electronics areas.
- Workforce development for professionals through continuing education. Materials to be developed include technical seminars, extended tutorials, short courses with hands-on laboratory or manufacturing experience, application notes, reference design documentation, and online professional training programs.

Materials developed under this Call for Projects will be "published" by PowerAmerica. PowerAmerica will not charge a publishing fee or page charges. However, PowerAmerica will require transfer of copyright to PowerAmerica but will allow use by the individual or institutions for other purposes provided the PowerAmerica logo is prominently displayed in a PowerAmerica approved location(s). In addition, PowerAmerica EWD material must be rolled out on a national basis. The Institute highly encourages the use of the Creative Commons (CC) license to ensure a quicker and broader dissemination of the materials developed using federal funds. Online material must adhere to the Americans with Disabilities Act (ADA) and PowerAmerica can assist with these requirements.

Topic 5.1 Documentation of Design and Process for GaN and SiC Based Devices (Up to $50K, multiple project awards, teaming encouraged)
The purpose of this topic is to create a repository within which best design practices for WBG semiconductor device fabrication can be published for educational and non-commercial purposes. The process must have already been validated by the applicant. The repository would include process flow information at a level of detail such that functional devices could be produced in foundry environments. This would be an "Open Process" flow containing no proprietary unit steps. Process flows that *do* contain proprietary unit steps should reference the published literature or patent owners where the intellectual property might be licensed. PowerAmerica will provide the repository infrastructure on its EWD Portal.

There are three aspects to this project: 1) The creation of an Open Process flow and its associated documentation with sufficient technical detail so that the designs can flow through a foundry without infringing on intellectual property; 2) Appropriate identification and documentation of any and all process flows containing intellectual property, and its restrictions, that would require licensing; and 3) A short instructional video on the new Open Process flow lasting approximately 10 to 16 minutes.

EWD invites proposals from the education community to:

1. Create and publish in electronic form documentation for detailed design and process descriptions for GaN and SiC switches and related WBG devices. The design should document 2D device simulations, CAD layouts (drawings and GDS2 files) including all the layers, detailed process travelers, and details of the unit processes that are unique to the technology such as Ohmic contacts, gate oxidation, passivation, implant profiles, implant activation, etc. The test results from prior implementation should also be included. Future enhancements should be suggested.
2. Make information available that is sufficient to provide a starting point for researchers and companies to begin developing new innovative manufacturing techniques to help expand the WBG industry and create new jobs. (Note: it is expected that the documentation will be updated yearly to establish a truly open-access foundry processes as a fabless approach to conduct manufacturing innovation research and to create innovative new products. As a reminder, the documentation should not contain any proprietary information from any source.)
3. Expect and encourage collaboration between members of the education community and the affiliated foundries to support open-access documentation that will enable the fabless approach

to WBG devices. As such, all proposals must include a mechanism to receive comments and suggested edits from users that will provide the basis for future revisions.

Topic 5.2 Short Course Development (1/2 day to 1 day options) (~$10 - $50K)
The purpose of this topic is to increase the number of short courses and improve their distribution among the PowerAmerica community and beyond for working professionals. Proposals should be for 1/2 day to 1-day short courses that must contain some type of physical demonstration or several substantial hands-on components. The final deliverable must include appropriate information about the additional cost of supplies and materials, and access requirements to equipment that may be needed. Materials developed under this program will be "published" by PowerAmerica. PowerAmerica will require transfer of copyright to PowerAmerica, but will allow use by the individual or institution, if applicable, for other purposes with the PowerAmerica logo attached. In addition, the developer or his or her proxy is expected to teach this course at one or more of the PowerAmerica Summer Workshops. This topic is for development of the workshop materials only. A separate subaward modification will be issued for expenses associated with the actual teaching of the short course at a PowerAmerica event.

Topic 5.3 Technology Transition Projects for WBG Semiconductors and Power Electronics (Up to $50K with a limit of 2 teams per institution)
The purpose of this topic is to identify technologies where basic principles have been proven and are at the working prototype stage. These technologies must have significant economic potential and be ready to transition into a licensable IP for industry to use and commercialize. These technology transition projects must involve interdisciplinary teams of students who will collect, analyze and develop data and materials that represent a credible approach and strategy for deploying a WBG product or system.

A manufacturing oriented approach considers the following that are important in transitioning technologies to manufacturing:

- Economic - problem identification and validation, market size and growth projection, product solution evaluations, cost of labor and materials, scale-up strategy, ROI specified over time periods, the payback period
- Operations management – supply chain management, inventory turns, and distribution chain management
- Product Development – Specification, design, test, packaging, etc.
- Regulatory Compliance to government and Industry standards e.g. EARS/ITAR, FCC, EPA, FDA, EMI, EMC, NEMA, UL labeling, OSHA, etc.
- General Administration - C-Suite responsibilities, HR, Legal, Sales, and Marketing.

Proposals should include:

1. A plan on how to assemble a multidisciplinary student team, with advisors, from engineering and other disciplines as appropriate
2. A technical description, done in layman's terms, of the proposed technology to transition (one page)
3. Proposed market segments including their current size and potential growth rate (one page);

4. Anticipated social and economic impact of the technology
5. Industry connections, or desired industry connections that PowerAmerica might be able to facilitate, which might provide mentorship.
6. A technology transition plan that includes how your team will do the following:
    - A plan outlining a strategy to present the technology to potential customers (10 slide deck max) where you ask them if they currently have a problem that this technology might solve, or do they know of other customers that might need this technology (typically want to speak with between 20 and 30 people)
    - Once the problem and customer has been identified, how will you use the technology to build a product that solves it
    - Build a supply chain needed for product manufacturing
    - Develop a plan for how to reduce materials and labor costs using advanced manufacturing techniques and compare this to the original prototype cost
    - Produce a product headcount driven scale-up manufacturing plan for the anticipated market size
7. Budget: Up to $20K can be allocated for appropriate faculty supervision and mentorship to provide on-site guidance. In addition, travel funds should be allocated for all PowerAmerica-funded students to present in person at the PowerAmerica Annual Meeting (typically January or February) and/or the PowerAmerica Summer Workshop (typically August). Student stipend/salary and travel to Raleigh, NC, should be included in the budget. Other costs as appropriate to advance the project, i.e. meeting with industry to see manufacturing processes, materials and supplies, and in limited cases purchase of market reports.

Topic 5.4 Development of Undergraduate and/or Graduate Teaching Labs (Up to $100K)
Both universities and industry are encouraged to participate. Projects are sought for development of undergraduate teaching labs that focus on WBG semiconductor device fabrication, device testing and analysis, or demonstrations of the advantages of wide bandgap semiconductors.

The first $10K of the award is to be used to develop a detailed outline and curriculum that is suitable for undergraduate or graduate teaching labs, and may range from the development of a new course to developing a lab module that can be distributed to other universities.

Proposals should attach anticipated budget. Development of hands-on lab modules is encouraged, but since the intent is to distribute high quality materials, the cost of consumables should be a consideration. Development and use of evaluation boards is encouraged. In some cases PowerAmerica may cover additional cost of board fabrication if suitable for laboratory instruction. In the case of specialized test equipment for testing and analysis, the requirements should be clear.

Topic 5.5 An Open Call for Education and Workforce Development Projects
The above projects are not an exhaustive list of PowerAmerica interests in education and workforce development. PowerAmerica will consider these and other ideas, especially if they have a significant impact on university education and workforce development. Their target can range from university

level through working professionals. Leveraging, expanding, and adding power WBG content to existing power electronics education programs will be considered.

Of particular importance are educational resources for working professionals that:

1. Stress the impact of SiC or GaN on power conversion and circuit topologies
2. Emphasize design considerations for switching high voltage and high frequency, and their impact on EMI and passive components.

Topic 5.6 Outreach to Late-Undergraduate and Early-Graduate Students for Recruitment to WBG programs at PowerAmerica Member Universities (Up to $50K, multiple project awards, teaming encouraged)

Outreach activities should focus on identifying exceptional students from non-PowerAmerica universities that have excellent power electronics and power engineering programs. A priority is to provide opportunities for underrepresented or displaced populations of U.S. citizens to participate in PowerAmerica programs. Recruitment activities for students identified as potentially having interest in continuing graduate work in WBG power electronics may include supporting student trips to the PowerAmerica member universities, trips to the PowerAmerica member meetings, and trips to the wide-bandgap power electronics related conferences with a strong PowerAmerica presence. The PowerAmerica universities may also team with their local industry or National Lab partners to propose cooperative education opportunities for the selected students.