PowerAmerica:
Next Generation Power Electronics Manufacturing Innovation Institute

Call for Projects for
June 1, 2017 - May 31, 2018

Issue Date:	Thursday, September 8, 2016
Submission Deadline for Concept Paper: https://ncsu.infoready4.com	Friday, October 7, 2016 9:00 PM EDT
Response (Encourage/Discourage Notification)	Friday, October 14, 2016
Submission Deadline for Full Applications: https://ncsu.infoready4.com	Friday, November 11, 2016 9:00 PM EDT
Expected Date for Selection Notifications:	January 2017
Expected Timeframe for Project Negotiations	February-March 2017
Project Start Date	June 1, 2017

Submission Information

- Questions regarding this opportunity can be submitted on the PowerAmerica website. https://www.poweramericainstitute.org/funding-opportunities/call-for-projects-2016/ An attempt will be made to answer all questions. Answers will appear publicly: https://www.poweramericainstitute.org/2016-call-for-projects-questions-and-answers/
- **Do not include any proprietary information in the Concept Papers**.
- Concept Papers are mandatory for proposal submission and the deadline is firm. An Encourage or Discourage recommendation will be provided to applicants. Full Proposals will only be accepted from Encouraged Concept Papers.
- We regret that Discouraged Concept Papers will not receive any further information.
- Full Proposals cannot be submitted 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.

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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. Only two (2) Concept Papers per division/site will be accepted from any organization. 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 commercialized. Paper studies or engineering analyses are not suitable for this program. It is expected that industry members would have already performed such studies. All university technical projects are required to involve two undergraduate students in the work plan.
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 with quantitative milestones are required. Templates for the required budget & budget justification, quad chart, and statement of project objectives (SOPO) will be available from the InfoReady website. Information that is proprietary, confidential, or a trade secret should be clearly marked. Up to two (2) Full Proposals can be submitted from each division/site of any organization.
Expected Award Amounts	Throughout this document, the dollar amounts listed are the funds that will be provided by PowerAmerica. **All projects require a minimum 1:1 cost match from the applicant.** Suggested project dollar amounts shown are estimates only, and will be adjusted based on the quality of the proposal. **Proposals with funding requests exceeding the PowerAmerica limits will not be considered.** **For teams, the dollar amounts suggested in the focus area description will be additive.**
Types of Funding Agreements	**Applicants 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	June 1, 2017 - May 31, 2018
Eligibility	**All industry applicants are required to have a U.S. manufacturing presence**. All other entities are required to be located in the U.S. All work must be performed in the U.S.
Cost Share Requirement	A minimum of 1:1 cost match is required on all projects. National labs may team to meet cost sharing requirements.
Multiple Applications	Up to two (2) Concept Papers can be submitted from each division/site of any organization. Up to two (2) Full Proposals can be submitted from each division/site of any organization. Each Concept Paper or proposal must describe a unique, distinct project.
Teaming	**Teaming among companies with complementary capabilities or in adjacent sub-sectors of the supply chain is strongly encouraged**. **Universities and National Labs are also strongly encouraged to team with industry** for market guidance, manufacturing insight, and pathway to commercialization**. For University/National-lab team projects, there will be an industry award plus an additional University/National-lab award per dollar amounts suggested in the focus area description. For company teams, each team member will receive a separate**

	award per dollar amounts suggested in the focus area description.
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, converter and inverter architectures, and packaging and manufacturing processes with the potential to improve their performance and lower their 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/Ampere of WBG devices and power modules ● Demonstrate the system level advantages of WBG devices in power electronics applications, and of WBG reliability ● Pathway to commercialization for industry-led projects ● Impact on U.S. manufacturing competitiveness ● Impact on workforce development and education ● Production of U.S. engineers with expertise in WBG power electronics

II. CALL FOR PROJECT DESCRIPTION

A. Background

PowerAmerica (the Institute) is part of the National Network of Manufacturing Innovation (NNMI), and is supported by the US 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, and supporting manufacturing, and creating jobs across the US 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 the development of advanced wide bandgap power semiconductor devices, converter and inverter architectures, 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 US 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 WBG industry.

The Institute strongly encourages teaming between companies and between companies 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. For teams, the dollar amounts suggested in the focus area description will be additive.

Figure 1 shows that the PowerAmerica Institute focuses on the TRL/MRL 4-7 readiness targets. **Basic science and exploratory scientific research are not appropriate for this program.** (https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html)

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	TRL 1:	Basic principles observed and reported	MRL 1:	Manufacturing feasibility assessed
	TRL 2:	Technology concept and/or application formulated	MRL 2:	Manufacturing concepts defined
	TRL 3:	Analytical and experimental critical function and/or characteristic proof of concept	MRL 3:	Manufacturing concepts developed
NNMI Target	TRL 4:	Component and/or breadboard validation in a laboratory environment	MRL 4:	Capability to produce the technology in a laboratory environment
NNMI Target	TRL 5:	Component or breadboard validation in a relevant environment	MRL 5:	Capability to produce prototype components in a production relevant environment
NNMI Target	TRL 6:	System/subsystem model or prototype demonstration in a relevant environment	MRL 6:	Capability to produce prototype system or subsystem in a production relevant environment
NNMI Target	TRL 7:	System prototype demonstration in an operational environment	MRL 7:	Capability to produce systems, subsystems or components in a production relevant environment
	TRL 8:	Actual system completed and qualified through test and demonstrated	MRL 8:	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production
	TRL 9:	Actual system proven through successful mission operations	MRL 9:	Low rate production demonstrated; Capability in place to begin Full Rate Production

Figure 1. Definitions of technology and manufacturing readiness levels.

Participation by Foreign Firms
Foreign owned firms may apply, provided they have substantial manufacturing and operational facilities and staff based in the US. **All work must be performed in the US.**

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 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
- RF devices and applications

C. Concept Papers

No proprietary information should be included in Concept Papers. Concept Papers should be submitted as a single PDF file and must include:

- 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. Indicate the intended level of membership. (https://www.poweramericainstitute.org/membership/)

- 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 the risk mitigation approach
  - Current TRL or MRL of proposed activity and expected level at end of 12 months
  - Describe the primary deliverable(s) and how it advances the Institute objectives
  - Identify SMART (specific, measurable, achievable, relevant, time-bound) metrics and a key Go/No-go decision point for the project.
- 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, and what products the project's result will replace or improve. (1 page)
- Teaming arrangement, description of roles, and list of key personnel (1 page)
- Gantt chart or timeline showing monthly progress and quarterly milestones
- Project Quad chart. Quad chart format is available from the InfoReady website.
- Budget estimate (sample format) given below

Concept Paper budget sample

	PowerAmerica funds	**Applicant Cost Match**
Personnel		
Equipment (>$5,000)		
Supplies & Materials		
Subcontract (team)		
Travel		
Indirect costs		
Subtotals		
Total project cost		

All Education and Workforce Development (Focus Area 5) Concept Papers must also include:

- Number of students involved in their role in the project
- Assessment techniques to be used (1 page)
- Methods and venue 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.

Full Proposals must include 4 separate files:

Items 1 - 6 as a single PDF file
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, 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 quarterly milestones in detail. **A minimum of one milestone per quarter is required with at least one Go/No-Go decision point at an appropriate juncture.**
6. Signed letter of commitment from the organization or university sponsored program office including a detailed description of the type and amount of cost share to be provided for the 1:1 cost match.
7. Quad chart containing no proprietary information suitable for public distribution. Quadrant slide format available from InfoReady website.
8. Budget and justification using the Department of Energy EERE - 159 form, available from InfoReady submission website. Include travel to Raleigh, NC for two (2), 2-3 day meetings and any student costs. Proposals with funding requests exceeding the PowerAmerica limits will not be considered.
9. Statement of Project Objectives (SOPO) using the format available from InfoReady website. The SOPO is essentially a 3-5 page detailed work plan that describes the specific project

activities that will be performed, the sub-tasks, 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 task summary (half page), followed by the subtask summaries (paragraphs), followed by the associated milestones, and deliverables.
- At least one milestone is required each quarter and should contain specific, measureable metrics related to the technology development.
- At least one critical Go/No-go milestone at an appropriate point in the project. For device and packaging proposals, announcement of a qualified commercial product with 1K pricing targets through a distribution channel such as Digikey. For application projects measured performance parameters of tangible hardware is required.

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 Technical Projects (Focus Area 2 - 4)
University technical projects 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, 3 - 5 minute video, and to attend the Undergraduate Research Scholar Institute concurrent with the PowerAmerica Annual Meeting (Typically January or February). 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, potential impact on industry
- Assessment techniques to be used (1 page)

E. Evaluation Criteria

PowerAmerica will assemble a 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: 20%) -** The extent to which the project, if successfully carried out, will make a valuable contribution to PowerAmerica. The project objectives are clearly stated, challenging, 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. 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 objectives of the project. Appropriateness, rationale, and completeness of the proposed Statement of Project Objectives. Degree to which the applicant has identified high risk challenges and presented reasonable mitigation strategies. There is a high degree of innovation, novelty or originality in the approach. 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: 40%) -** The economic benefit to the US and a US company is clear; with US manufacturing being advanced and with US product innovation. A pathway to market and US commercialization plan 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 and above should be stated. University projects should show a link to industry and a proposed path for advancing the technology up the TRL scale, validating the technology, tech-transfer, licensing, or co-development with industry. Preference should be given to proposals that generate or sustain US manufacturing jobs.

Education Projects (Focus Area 5)

1. **Alignment to PowerAmerica Education and Workforce Development Objectives (Weight: 33.3%) -** If successful, will this project proposal make a unique and important impact in education and workforce development that promotes job creation in manufacturing that

specifically targets the WBG power electronics industry and the products enabled? Is the project proposal appropriate, and complete according to the Statement of Project Objectives?

2. **Relevance and Approaches to Innovation in Pedagogy (Weight: 33.3%)** - 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 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: 33.3%) -** 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, needed 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 and Institute Sustainability
Focus Area 2: Foundry Operations and Devices
Focus Area 3: Packaging and Power Electronics Foundry, Test and Reliability
Focus Area 4: Accelerating WBG Adoption for Commercial Application
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 cost match. **Proposals with funding requests exceeding PowerAmerica limits will not be considered.**

A. Focus Area 2: Foundry Operations

Applicants must commit to deliver engineering samples within 12 months for all FA 2 projects. Pricing information for 1000 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 Development (Up to $1M)
The purpose of this topic is to support the development of a U.S.-based Silicon Carbide foundry that leverages existing 150 mm or 200 mm silicon device fabrication infrastructure, and will be accessible to industry and universities. The goal is to build the infrastructure to run full device process flows from wafer with epitaxy to qualified devices. At the early stage of infrastructure development, **t**he wafer can leave the foundry for limited unit steps (heated implantation, anneal, backside processing, etc.). 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 including non-SiC experts. This includes implementation of process development kits (PDK), and process and quality controls that meet or exceed industry standards. The foundry should leverage existing equipment, ideally have silicon 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 university work and open foundry process development at reasonable costs. The ability to support a fully open PowerAmerica baseline process for SiC power devices is desirable. The foundry is expected to exploit existing silicon manufacturing economy of scale to reduce SiC manufacturing cost.

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).

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 including non-GaN experts. 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.

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 economy of scale to reduce lateral GaN manufacturing cost. 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).

Topic 2.3 Silicon Carbide Devices (Up to $500 K for Industry, and up to an additional $250 K for Universities and National labs teaming with industry)

Industrial device proposals should primarily be directed at implementing device flows to produce competitive devices at volume within the open foundry. This usually implies that an existing device with known metrics and processes is being transferred, and/or is being improved. Examples of device improvements include improvements in yield, better edge termination, die size reduction, use of trench isolation, thinning of substrates, and improved integration of diodes. As SiC devices with blocking voltage in the range of 650-1200 V are commercially available, the majority of industrial proposals are expected to focus on devices with a blocking voltage range of 1.7-10 kV. 1200 V MOSFETs with a very low specific on-state resistance of less than 1.5 $m\Omega\ cm^2$, as well as 650 V JBS diodes with a room temperature forward voltage drop of less than 1.1 V, and a leakage current of less than 0.1 mA/cm^2 of total area at 175 °C will be considered. PowerAmerica is also interested in the development of rad-hard switches to address the DoD and aerospace applications.

Devices with suitable metallization on top and bottom to facilitate double-sided packaging will also be considered.

PowerAmerica has developed a baseline 1200 V SiC MOSFET process at XFab (150 mm SiC) that can be licensed by interested parties to accelerate their SiC offerings. Inquire with PowerAmerica CTO Victor Veliadis at: jvveliad@ncsu.edu.

- 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 1000 unit volume pricing, or improvements in an existing product's market competitiveness.
- Proposals should be accompanied with a suitable packaging strategy, ideally resulting in power modules that would be accessible through PowerAmerica's device bank for members to use for application development. Power module 100 unit budgetary pricing should accompany product release.
- Industry proposals for device blocking voltage range of 3.3-10 kV should include fabrication of at least five lots.
- University proposals for device blocking voltage range of 3.3-10 kV should include fabrication of at least three lots.
- Universities are expected to use the open foundry and to team with industry to provide potential pathways for commercialization.

Universities may also team with a foundry to focus on open process development. The goal of this teaming effort would be to have universities focus on key unit steps within specific device flows, and to document and build a baseline PDK. This open process would be made available to industry members and the foundry to optimize their production purposes. The open process would also serve as a platform for universities to train a next generation of experts in silicon carbide power device design and manufacturing.

Topic 2.4 PowerAmerica Silicon Carbide Device Bank (up to $500K per Industry Project)
Proposals are requested for the development of qualified 3.3 kV and 10 kV MOSFET packages and modules for the PowerAmerica device bank. The idea behind the "Device Bank" is that the devices are fabricated, screened, packaged, and delivered to PowerAmerica. The packaged devices and modules can then be used in future PowerAmerica applications programs accelerating the rate of adoption of high voltage devices. It is assumed that the proposer (or the team) has qualified 3.3 kV and 10 kV SiC MOSFETs. This program is not to be used for developing the technology from scratch but simply adjusting the qualified designs with minimal development. The sole purpose of the program is to create enough packaged devices and modules to be used as engineering samples for subsequent power electronics demonstrations, research, SPICE model and circuit topology development, etc. These

packaged devices and modules will be supplied to PowerAmerica applications members for the above stated purposes, at the discretion of the CTO and with the consent of the DOE Technical Manager.

The proposals should include the following details for both the 3.3 kV and 10 kV MOSFETs:

1. Total number of wafers to be run assuming a total funding of $1M including the 50% cost share and taking into account the labor, overhead and other miscellaneous costs.
2. Total number of expected functioning packages and modules at each voltage to be delivered to PowerAmerica.
3. A soft copy of characterization results for each delivered module and package.

Topic 2.5 Gallium Nitride Power Devices
(Up to $500 K for Industry, and up to an additional $250 K 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 that 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.

Universities may also team with the foundry to focus on open process development. The goal of this teaming effort would be to have universities focus on key unit steps within specific device flows, and to document and build a baseline PDK. This open process would be made available to industry members and the foundry to optimize for their production purposes. The open process would also serve as a platform for universities to train the next generation of experts in Gallium Nitride power device design and manufacturing.

The goal is to create an Open Access Process at a 150 mm or 200 mm Commercial Foundry for Gold-free 200 - 900 V, enhancement mode (normally off) lateral GaN power HEMTs on GaN/Si and/or GaN/SiC with reduced cost, better reproducibility and improved reliability. Open processes for integrated GaN devices for gate drivers may be considered if appropriate evidence of market need, and pathway to commercialization is presented.

To qualify an open foundry baseline process, there is some leeway in choosing a lower voltage to qualify devices, since this may facilitate obtaining lower cost epitaxy and wafers, but proposals that qualify devices at less than 200 V are discouraged, unless there is sufficient commercial application reason. The open foundry basic process should produce a switch (normally-off) with at least the minimum parameters of a leakage current of <1 mA/cm^2 at the rated voltage at 25 °C, and a rated current of at least 10 A at a forward voltage drop of 1 V at 25 °C. The device specific on-resistance (expressed in mOhms*cm^2) should be lower than those of Si and SiC at similar rated voltage.

B. Focus Area 3: Packaging, Power Electronics Foundry, Test & Reliability

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

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

Sub-Topic 3.1a High Performance Packages for Power Modules and Gate-Drive Boards that exploit the positive attributes of WBG devices in low thermal impedance, low inductance, at high temperatures are needed for 3.3-10 kV devices. Packages being developed for high volume 200-1700 V applications should include partnerships with system integrators. Proposals for discrete packages are discouraged. 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 by and accommodate the module needs of the WBG devices community are sought. Packaging houses with existing volume Si 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 commercialize their innovations.

Sub-Topic 3.1b 6.5 kV Cascode Half Bridge Modules

The goal of this effort is to provide 6.5 kV 100 A SiC cascode half bridge modules by stacking multiple lower voltage vertical SiC JFET devices and connecting them in the cascode configuration with a low voltage Si MOSFET. Above ~5 kV, SiC devices have a relatively thick drift layer. If bipolar conduction occurs in these thick epilayers, Basal Plane Dislocations (BPDs) give rise to stacking faults and rapid forward voltage degradation occurs. Although MOSFETs are unipolar devices, precautions must be taken to never allow their built-in PiN diodes to go into a forward bias state. This is accomplished by blocking the body diode with an external Schottky diode and by using a JBS configuration where injection from the built-in p-type grid is suppressed by design and by poor Ohmic contacts to implanted p-type regions. Alternatively, a SiC JFET based cascode half bridge module allows for 6.5 kV voltage operation, without the design limitations and deleterious effects associated with BPDs. Similar projects using 1200 or 1700 V SiC MOSFETS in series will be considered.

This project does not aim to develop the JFET and cascode configuration module technology from scratch, but rather to optimize module design with minimal development. The task primarily involves packaging, minimizing inductance, using snubbers for transient voltage suppression, testing modules in static and dynamic modes (double pulse testing for instance), comparing with Si and SiC MOSFET modules, and establishing module reliability. The main purpose of the program is to create modules to be used as engineering samples for power electronics demonstrations, research, SPICE model and circuit topology development, etc. These modules will be supplied to PowerAmerica members for the above stated purposes, at the discretion of the CTO and with the consent of the technical DOE Manager.

Assuming a total funding of $500K, including the 50% cost share, and taking into account the labor, overhead, and other miscellaneous costs, the proposals should state the total number of expected functioning modules to be delivered to PowerAmerica on a best effort basis. A soft copy of characterization results for each delivered module should also be part of the deliverables. Power module 100-unit budgetary pricing should accompany product release.

Topic 3.2: Reliability and Testing Services for SiC and GaN (up to $250K for Industry, and up to $200K for University 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 Reliability of SiC MOSFETs under positive and negative gate bias stress at elevated temperatures and forward bias stress of the built-in body diodes, this subtopic is focused on the identification and systematic cataloging of their degradation mechanisms[1] with the focus on 1200V/20A devices that characterize (1) V_{th} shifts due to DC positive (+15, +20 V) and DC negative gate bias (-10, -15 V) at 150 °C, (2) drain-source on resistance stability and leakage currents subsequent to the forward bias stress of the body diode in commercially available SiC MOSFETs from more than one vendor. Measurements should be conducted for up to 1,000 hours stress.

Sub-Topic 3.2b High Voltage SiC Device Reliability 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. Wafer mapping at various device fabrication stages should be performed to correlate device performance to underlying defects. Implementing room temperature implantations at high yields is critical for manufacturing cost reduction.

Sub-Topic 3.2c 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. [2] Wide bandgap semiconductor devices offer opportunity to dissipate

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[1] Aivars J. Lelis, Ron Green, Daniel B. Habersat, and Mooro El. "Basic Mechanisms of Threshold-Voltage Instability and Implications for Reliability Testing of SiC MOSFETs." *Electron Devices, IEEE Transactions on* 62, no. 2 (2015): 316-323.
[2] "Power MOSFET Avalanche Design Guidelines," Application Note AN-1005, http://www.vishay.com/docs/90160/an1005.pdf

significant avalanche energy at high operating junction temperatures.[3] Proposals are sought that measure single and repetitive inductive avalanche energy of commercially available wide bandgap power devices and engineering device samples at room and elevated junction temperatures typical for their operating conditions as well as the short-circuit capability. 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.

[3] Aktas, O.; Kizilyalli, I.C., "Avalanche Capability of Vertical GaN p-n Junctions on Bulk GaN Substrates," *Electron Device Letters, IEEE* , vol.PP (2015), no.99, pp.1-3. doi: 10.1109/LED.2015.2456914

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

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

(Up to $400K per Industry Projects, up to $200K per University Projects, and up to $600K per Collaborative Industry/University Projects)

The Institute is seeking power electronics converters and inverters to further develop wide bandgap power semiconductor applications, which can potentially have large impacts on energy efficiency, weight and volume reductions, and can be widely deployed. Commercial 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 vehicles, hybrid cars, heavy-duty vehicles, aeronautics and unmanned systems. Power electronics are principally needed to condition power to drive systems efficiently. However it is increasingly important to 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. Aeronautic systems have long lead time for adoption and reliability is paramount, but significant system level advantages can be obtained by reducing the size and weight of the power electronics. For commercial aerospace there is increased electrical demand to supply power to entertainment, communications, and auxiliary systems. Unmanned systems are expected to continue to be significantly constrained by the capacity of energy storage and the advantages offered by WBG in size, weight and efficiency are significant. In all these systems electromagnetic interference, electromagnetic compatibility, thermal management, form factor and reliability remain significant design considerations. Proposals in this category are requested for:

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 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 will feature 12.47 kV three-phase AC input, and 350-1000 V DC output and should meet or exceed the following specifications: 350 kW output at 1000 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 protections.

Sub-Topic 4.1b SiC Inverter for Heavy Duty Vehicles (200 kW, 1050 V DC Bus)

Project should include deployment 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 – 105 °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. 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.

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. Proposals should include cost models for energy savings and cost of ownership. Proposals are requested for:

Sub-Topic 4.2a 100 kW Commercial PV Inverter

Demonstrate a commercial prototype 100 kW transformer-less photovoltaic inverter with CEC efficiency > 96%, input voltage range of 680-900 V, 3 phase AC output of 480 V, power density exceeding 5 kW/kg, and a ground leakage current below 300 mA. High bandwidth controller is desirable for enhanced primary frequency response.[4] The inverter must meet commercial EMI specifications per FCC Part 15.

Sub-Topic 4.2b Transformerless Medium Voltage Central PV Inverter

Demonstrate 200 to 500 kW transformer-less photovoltaic inverter block paired with high-gain boost converters using 900 - 1500 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[5] and limiting the transformer power transfer capability at higher switching frequencies used by WBG devices. Progress in high-gain boost converters[6,7,8,9] demonstrates potential for reducing cost and size of passive components of central PV

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[4] "FERC Seeks Comment on Provision, Compensation of Primary Frequency Response," Federal Energy Regulatory Commission, February 18, 2016, Docket No. RM16-6, Item No. E-2, Notice of Interest.

[5] 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.

[6] 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.

[7] Rosas-Caro, Julio Cesar, et al. "DC-DC multiplier boost converter with resonant switching." Electric Power Systems Research 119 (2015): 83-90.vd

inverters. Overall CEC efficiency > 97.5%, exceeding 2 kW/kg and inverter output connected to medium voltage distribution system 13.8 kV AC are desirable. Reactive power support[10], ground fault[11] and line transient protections[12] are required.

Sub-Topic 4.2c 1 MW Inverters for Wind Applications
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,[13] reactive power and primary frequency response.[14]

Sub-Topic 4.2d 200 to 500 kW Inverter Blocks for Medium and Large Wind.
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.[15,16] 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, 1200 V or 1700 V power transistors, designed for high reliability. The machine voltage should be higher than 690 V AC.

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, 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 energy consumption of data centers, power supplies for cellular RF communications, power supplies and adapters for consumer electronics including computers and laptops, enterprise equipment, and cell phone wireless charging, and LED driver electronics. Proposals are requested for:

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[8] 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.
[9] Gonzalez-Hernandez, Jose Genaro, et al. "Bootstrap cascaded multilevel converter." IEICE Electronics Express 11.17 (2014): 20140561-20140561.
[10] Abraham Ellis, et al. "Reactive Power Interconnection Requirements for PV and Wind Plants – Recommendations to NERC," SANDIA REPORT SAND2012-1098, February 2012.
[11] Solar America Board of Codes and Standards: Ground-Fault Detection Blind Spot. http://www.solarabcs.org/about/publications/reports/blindspot/
[12] Rich Seguin, et al. "High-Penetration PV Integration Handbook for Distribution Engineers," NREL Technical Report NREL/TP-5D00-63114, January 2016.
[13] 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.
[14] 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.
[15] 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.
[16] 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 follow 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 Cell Phone Wireless Chargers
Most wireless phone chargers have a separate AC adapter. An integrated unit with AC to DC efficiency above 80%[17], 10W output power and power density exceeding 3 W/in^3 is desirable. It must comply with FCC Part 15 and/or Part 18.[18]

Sub-Topic 4.3e High Efficiency GaN-based LED Drivers
Dimmable using residential dimmers with output power range of at least 0.5 to 10 W. Operation in high hat fixtures is required.

Topic 4.4 Enabling Subsystems for High Voltage Systems and Energy Efficient Motor Drives
There is significant Institute interest in potential applications of 3.3 kV - 15 kV wide bandgap semiconductors. It is unclear what the fundamental building block for high voltage systems should look like. When considering the design of systems where reliability is the critical performance parameter, it is unclear if industry should pursue 3.3 kV devices because of perceived advantages in reliability, or be more ambitious and use 10 kV devices that may need to be significantly de-rated when implemented into critical systems. The development of 3.3 kV and 10 kV power modules, and having them available in sufficient quantity and quality to be field tested in systems is important. Furthermore, being able to control and monitor the building blocks is important. Proposals are requested for:

Sub-Topic 4.4a Medium Voltage Gate Drives to enable fast switching of 10 kV SiC power transistors. Gate drive minimum isolation voltage should be 15 kV, should include desaturation protection, junction temperature protection and low capacitance power supply. Minimum switching at 6 kV and 20 A needs to be demonstrated under double pulse test conditions. Testing should include isolation

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

voltage and dv/dt immunity. Commercial release of a high voltage gate drive is expected with budgetary unit pricing.

Sub-Topic 4.4b Asynchronous Microgrid Power Conditioning System (Microgrid PCS) Connector to Macrogrid

The Institute seeks to develop an Asynchronous Microgrid Power Conditioning System Connector to Macrogrid, which can be a modular MVAC (13.8 kVAC) to MVAC (4160 VAC and 13.8 kVAC) 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 common coupling (PCC) 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: 4160 VAC and 13.8 kVAC. This Microgrid PCS solution should enable 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 as well as 4.5 kV/6.5kV SiC JFET based super cascode 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 micro grid 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 13.8kV MVAC to MVAC (4160 VAC and 13.8 kVAC) 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 4.4c MV Motor Drive Inverter

Demonstrate a 200 kW inverter for motor drive applications with a > 3kV DC bus using 3.3 kV SiC switches, with a fundamental frequency > 500Hz, a switching frequency > 5 kHz, 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.

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

Continued additions 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

[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.

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.

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 Subtransmission Power Transformer

An 138/115kV to 34.5 kV, 40 MVA or similar subtransmission 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

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[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.

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 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.

PowerAmerica

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 generation power electronics industry using wide bandgap semiconductor technologies. The PowerAmerica community has a unique opportunity to excite young people from pre-college to 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 promoting this technology.

The EWD focus area is open to all PowerAmerica members **AND** to any 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.

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

- Instructional laboratories and associated experiments that focus on an application of choice and include a design project that firmly cements the information into knowledge;
- Short courses–1/2 day to 3 days 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 - 2 minute to 8 minutes in length, and
- Purely WBG informational videos
- Associated short white papers targeting the general public, NSF's Advanced Technological Education (ATE) Centers, NIST's Manufacturing Extension Partnership (MEP)s and small and medium enterprises (SME)s to be used on the EWD Portal.

Of special interest to EWD are projects that are created by multidisciplinary and cross-institutional collaborations. Lastly, all submissions are highly encouraged to use new and innovative forms of instructional design, pedagogical delivery, and with emphasis on multiple mobile platforms. Online material must adhere to the Americans with Disabilities Act and PowerAmerica can assist with these requirements.

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.

Due to the mobile communications technologies of today–social media, etc.–and the new research findings in student learning modalities, this Call for Projects provides a significant opportunity for both content and instructional design experts to collaborate and create the future of education and training.

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 to all 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 that will lead to new workforce 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.

Proposals must include the following information:

1. The individual or team member's experience in the design and processing of WBG devices including test results and procedures used to obtain the results
2. A proposed outline of the material to be covered,
3. A timeline for completion of tasks that includes quarterly milestones that are quantitative, and that contain a final Go/No Go milestone decision point, and
4. A detailed budget.

Topic 5.2 Documentation and the Prototyping of WBG Power Electronics Applications (Up to $4K for a student project no cost share (2 applications max/proposal) and $10K for more substantial projects with cost share (2 applications max/proposal)

The purpose of this topic is to add design practices and associated performance data for WBG power electronics applications for the designs that have already been demonstrated. These design will reside on our EWD Portal repository for educational and non-commercial purposes.

Reference design boards are effective ways for companies to illustrate the potential of their specific chip or module and for engineers to begin prototyping new hardware and associated software as the final board for manufacturing is being developed. Having a searchable hardware and software design repository will serve as a resource for product optimization solutions or ideas. Potential Projects fall into two categories:

- **Design Documentation**, i.e. CAD files, software code, simulation results, bill of materials, and measured performance parameters.

- **Design Practices**, i.e. best practices in EMI, EMC, thermal design, gate driver design, component selection, and co-optimization of parameters to maximize system efficiency and performance to minimize cost.

Design Documentation must provide sufficient information to actually "build" the design or significantly speed up the design of similar systems. In general, it is the design of the power electronics subsystem that is of interest, i.e. the design of the charger, and not the design of the car.

Design Practices must be narrowly defined and targeted to a specific design issue. One way to keep the focus would be to provide information similar in scope to a well-written textbook chapter, several weeks in a college level course, or what might be obtained in an industry-focused short course.

Topic 5.3 Short Course Development and the Instruction (1/2 day and 3 day options) (~$5K to $20K)

The purpose of this topic is to increase the number of short courses and improve their distribution among the PowerAmerica community and beyond. Proposals should be for 1/2 day and 3 day short courses that contain some type of physical demonstration (1/2 day) or several substantial hands-on components for the 3 day. 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. Proposals should include between 3 and 5 topics for consideration. In addition, the developer or his or her proxy is expected to teach this course at one or more of the PowerAmerica Summer Institutes or Workshops.

Topic 5.4 Technology Transition Projects for WBG Semiconductors and Power Electronics (Up to $25K with a limit of 2 teams per institution, or ERC Center)

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 identified and be ready to transition into a licensable IP for industry to use and commercialize.

Technology transfer from the laboratory to saleable product by a company is a long and arduous endeavor and most of the activity to identify and validate problems, design, manufacture, market, sell and make revenue is the purview of industry and not part of the missions of universities or governments.

EWD wants to approach technology transfer from a "manufacturing" perspective. This approach will help centers and institutes to learn how to enhance and advance their technologies up the TRL/MRL ladder.

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

- Economic - problem identification and validation, market size and growth rated, product solution evaluations, cost of labor and materials, scale-up strategy, ROI specified over time periods, the time period to return the initial investment
- 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 MBA students from any business school
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. Current industry connections, or desired industry connections that PowerAmerica might be able to facilitate, which might provide mentorship current **manufacturing** practices and typical steps necessary in transitioning a technology to a product generating revenue
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 1,000, 10,000, and 100,000 units per month, and
- Develop a simple business model based on the [Osterwalder Business Model Canvas] and identify the required ROI technology to justify manufacturing the product.

7. Budget: Up to $5K can be allocated for appropriate faculty supervision and mentorship to provide on-site guidance. In addition, travel for up to 2 students to present the project at a PowerAmerica Workshop and the progress to date at the PowerAmerica Annual Meeting and Open House in Raleigh, NC, to industry and government officials. 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.

Student teams must attend a monthly webinar to receive guidance, share experience with other teams, and report project status to PowerAmerica staff. The student's university's policy on excused absences will apply for that student.

At the conclusion of the project, the student team will deliver:

1. A videotaped 3-minute "elevator speech" (points will be deducted if a video is longer that 3 minutes) that describes the technology, problem to solve with WBG power electronics and who has it, the market size and its growth rate, and a high-level description of how your team is going to solve the problem. (Note your video must adhere to ADA policies. See you university IT or legal staff for details.)
2. Create a poster describing the impact of the technology and how it would be manufactured.
3. A written report, proprietary to PowerAmerica and the team, documenting a plan to transitioning their technology to manufacturing.
4. An executive summary report that is suitable for public sharing.
5. A public presentation to industry, and venture capitalists.
6. A manufacturing plan for producing the product with appropriate industry partners that includes a written statement of proposed objectives and detailed plan to facilitate commercialization.

Important components include: professionalism; leadership; teamwork; and creativity. As such, the quality, comprehensiveness, and presentation of all deliverables is critical.

Topic 5.5 Development of Undergraduate and/or Graduate Teaching Labs (Up to $100K)
Both universities and industry are encouraged to participate. Graduate students and Postdocs may participate with a letter of support from their supervisor. 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 $5K 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. Upon successful completion of this, a Go/No-go decision will be made by the PowerAmerica staff. After that, if a "Go" decision is made, the remainder of the funds will be released to complete the project. The quality and impact of the report determines if a "Go" decision is made.

If the "Go" decision is made, the funds may be used for the implementation of a course and for salary or materials and supplies related to course development. 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 5.6 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 STEM education and workforce development. Their target can range from pre-college through to working professionals.

Of particular importance are educational resources for working professionals that:

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