Advanced Manufacturing Office Peer Review

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PowerAmerica

May 28-29, 2015

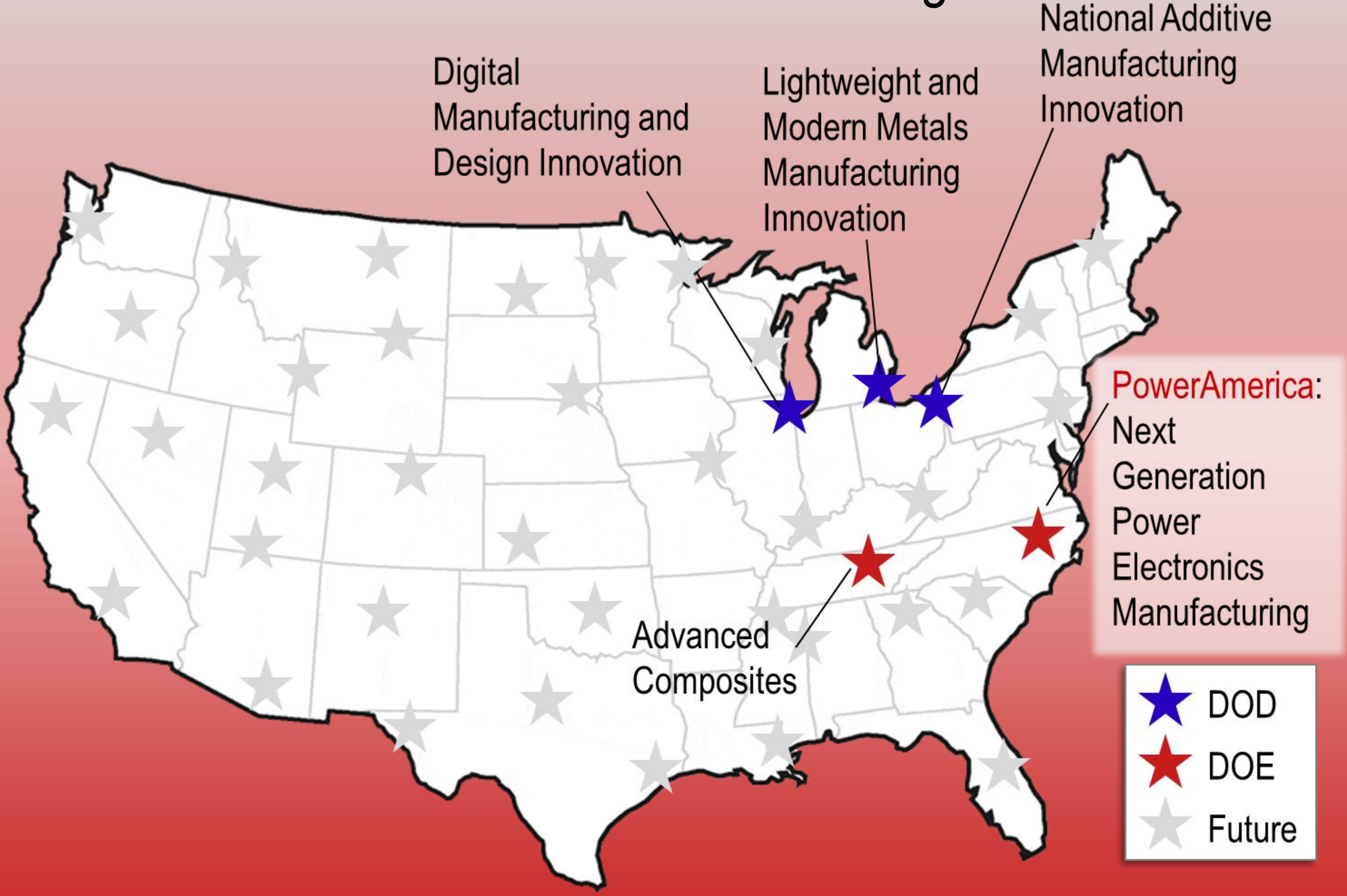
Technology and Manufacturing Readiness Levels
(Transitioning technology through valley of death)

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
TRL 4:	Component and/or breadboard validation in a laboratory environment	MRL 4:	Capability to produce the technology in a laboratory environment
TRL 5:	Component or breadboard validation in a relevant environment	MRL 5:	Capability to produce prototype components in a production relevant environment
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
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

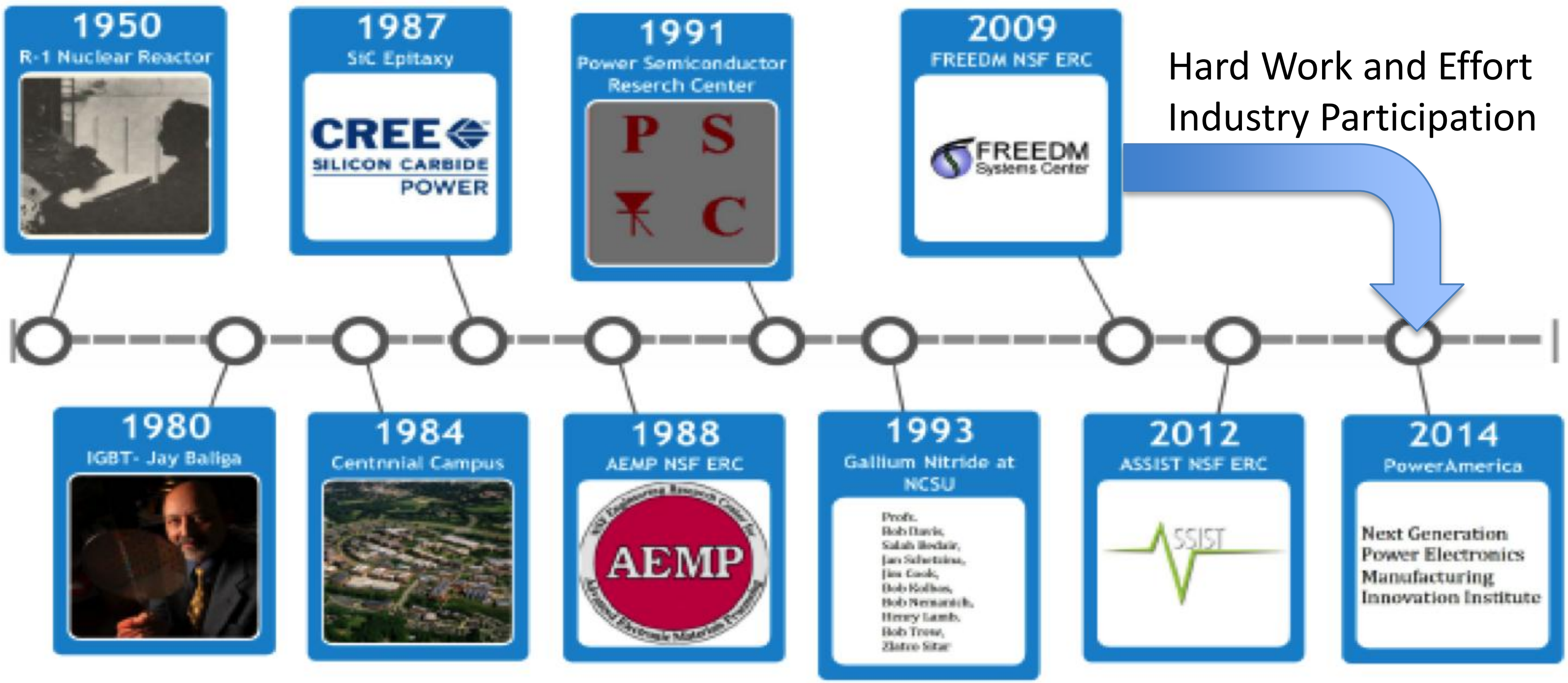
NNMI Target (TRL 4–7 / MRL 4–7)

Source: NNMI prelim design report.

National Network for Manufacturing Innovation



History of Collaboration and Investment



Partnerships

UCSB University of California Santa Barbara
VirginiaTech Invent the Future
ASU Arizona State University
Florida State University
CREE
USCi United Silicon Carbide, inc.
transphorm
Monolith Semiconductor Inc.
X FAB
Arkansas Power Electronics International (APEI)
John Deere
Toshiba Leading Innovation
ABB
Naval Research Laboratory Washington, DC
NREL National Renewable Energy Laboratory

Developing advanced manufacturing processes to enable cost-competitive, large-scale production of wide bandgap semiconductor-based power electronics, which allow electronic systems to be smaller, faster and more efficient than power electronics made from silicon.

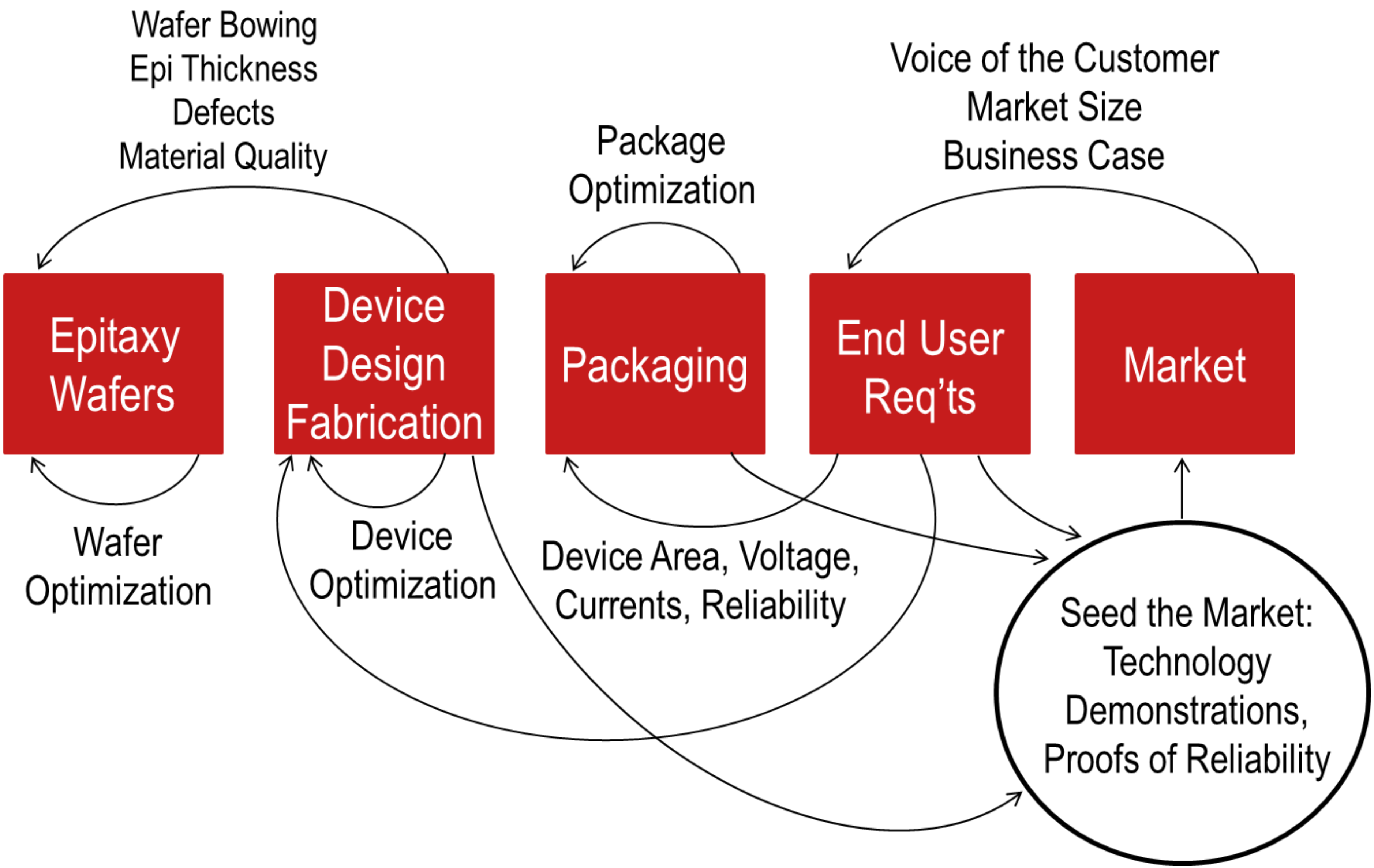
PowerAmerica Mission Summary

– US Manufacturing Competitiveness and Impact
  - Job Creation, Technology Innovation, Energy Savings

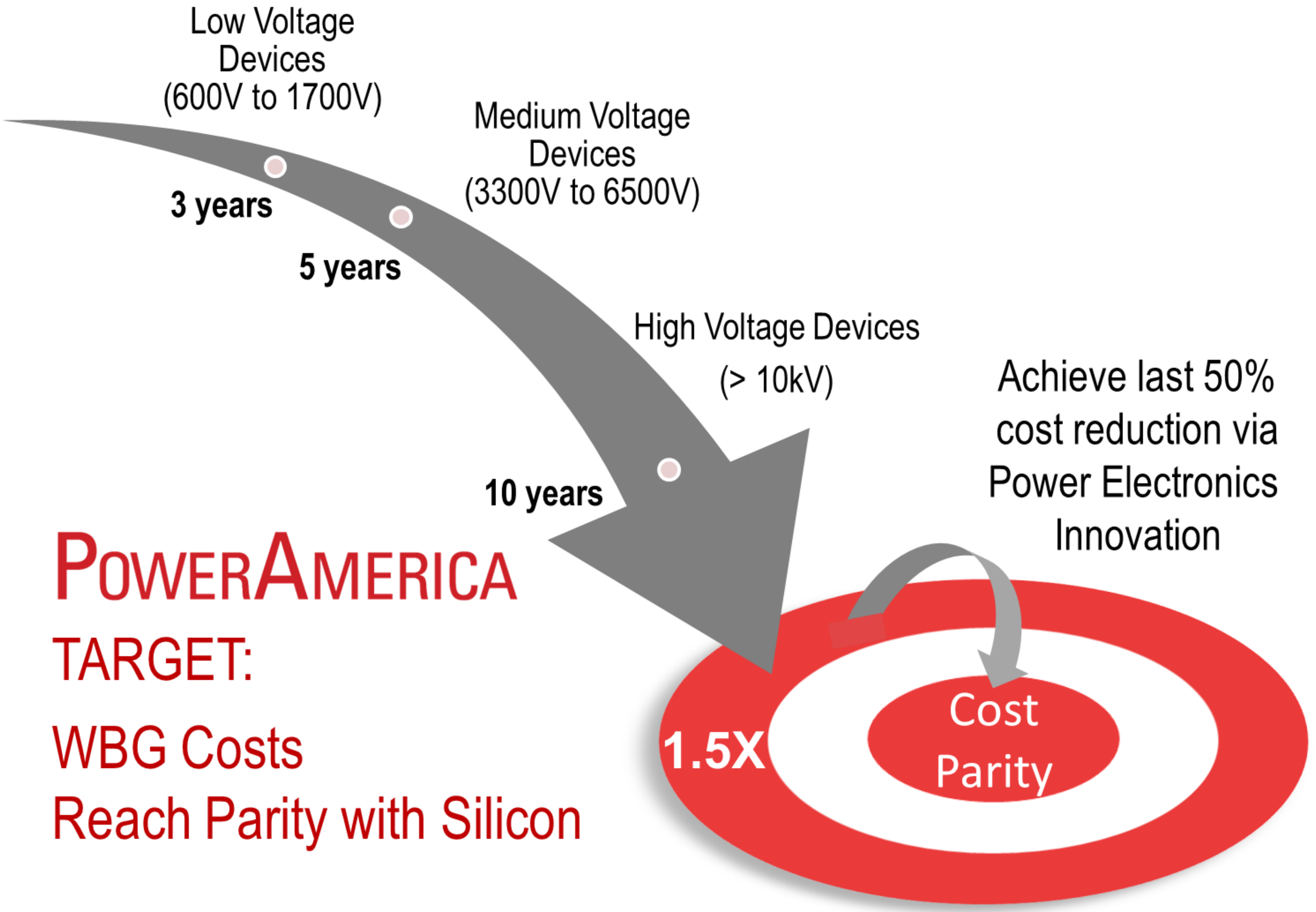
– Reduce Cost of Wide Band Gap Semiconductors
  - Foundry Concept.
  - Increase volume of applications.

– Increase Confidence in WBGS Power Electronics
  - Demonstrations of WBG PE System Advantages and Reliability.
  - Improve Knowledge Base of How to Design WBG PE Systems.

Optimizing the Power Electronics Industry



PowerAmerica Reducing Cost of Wide Band Gap Power Devices



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TARGET:

WBG Costs Reach Parity with Silicon

Silicon Carbide and Gallium Nitride

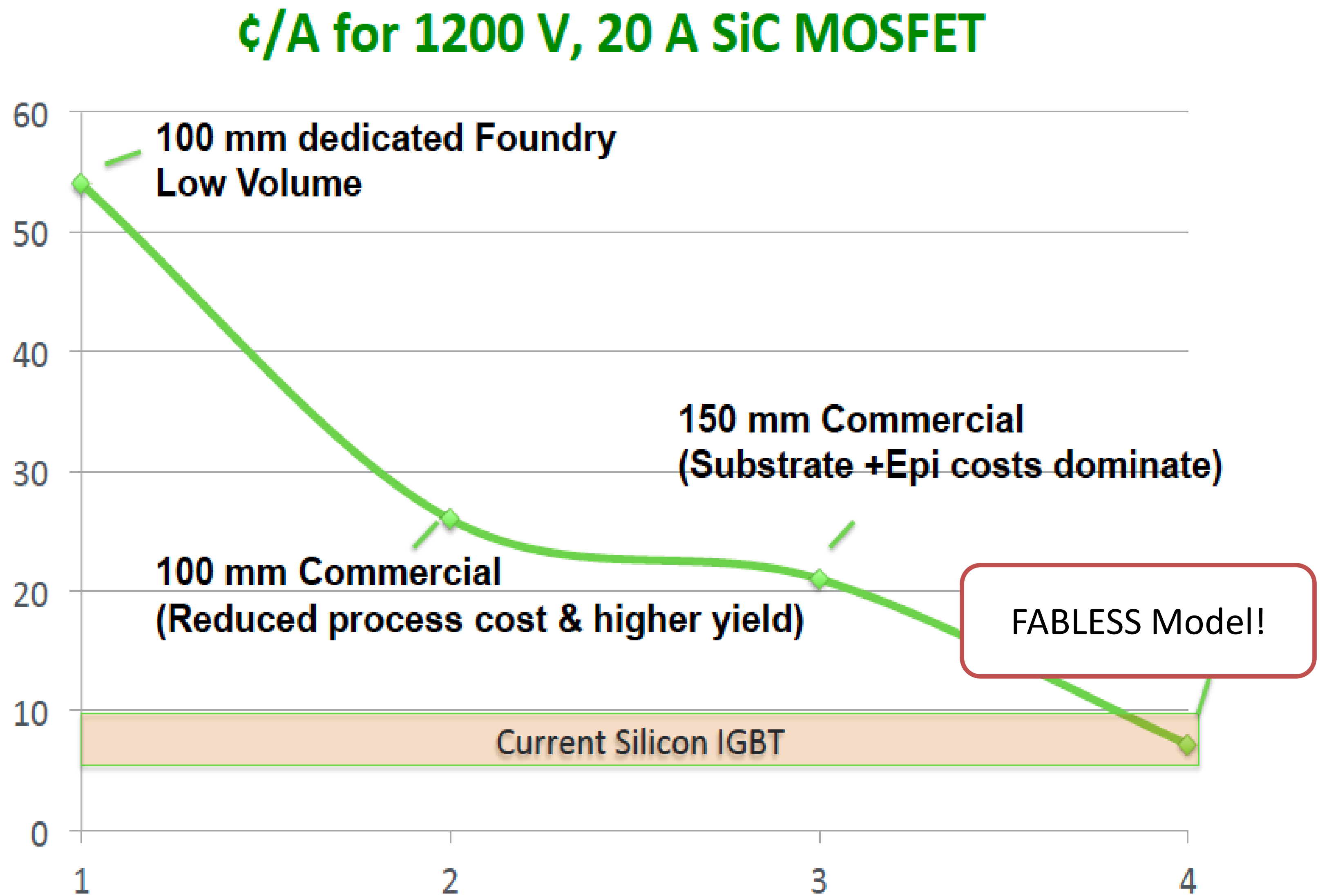
- Wide Band Gap Semiconductors for Power Electronics
  - Silicon Carbide: 1200 V, 1700V, 10 KV Diodes and MOSFETS
  - Gallium Nitride: 600-900 V

- Operate at Higher Temperatures
- Block Higher Voltages
- Switch Faster with less losses
- Smaller Passive components
- Substantial System Level Benefits

- Potentially More Reliable

- Physics is clear.... But adoption is slowed by
  - Cost compared to silicon devices
  - Perceptions about reliability

Reducing Cost of Wide Band Gap Power Devices



PowerAmerica Emerging Synergistic relationships

:

(Team: APEI, CREE, Toyota, Oak Ridge, ARPA-E)

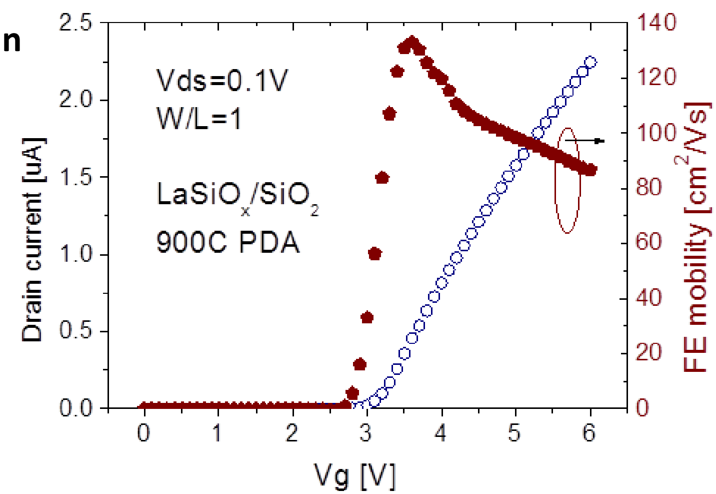
Arkansas Power Electronics International Inc.'s High-Performance Silicon Carbide-based Plug-In Hybrid Electric Vehicle Battery Charger

Building Foundry Relationships:

(Wafers starting to Run through SiC foundry)

Three Examples that Span the Institute

- Improved Devices
- Low cost via foundry model
- System level benefits obtained from WBG Semiconductors



Significant Increase in peak mobility

V. Misra @ NCSU and Industry Member

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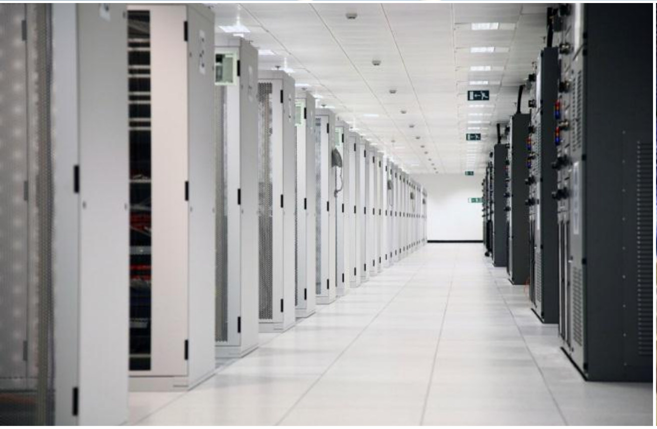
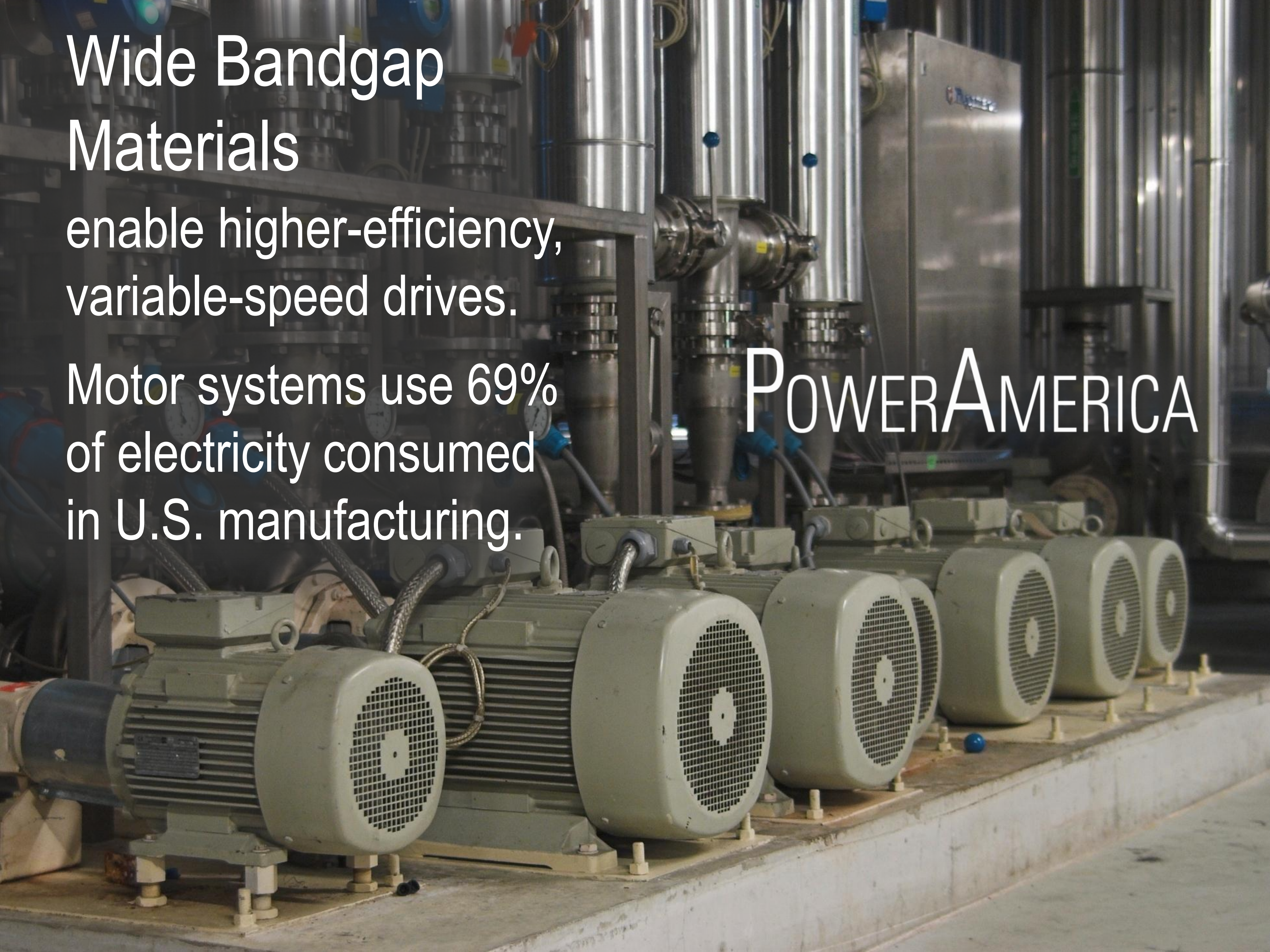


Applications


PowerAmerica
E
Wide Bandgap
materials cut electricity losses during charging by 66%


Wide Bandgap Materials
enable higher-efficiency, variable-speed drives.
Motor systems use 69% of electricity consumed in U.S. manufacturing.
PowerAmerica


PowerAmerica
Wide Bandgap
Reduce Losses
Improve Efficiency
Control Power Quality
Better Grid interface
Decrease Complexity
Improve Reliability

Case Study of Wind Energy

- Example of a application where Wide Band Gap Semiconductors provide an enabling component.
- Small part of the cost of the system
- Important in reliability and lowering system losses
- Part of National Strategy for Clean Energy
  - ~ 230,000 jobs potentially created

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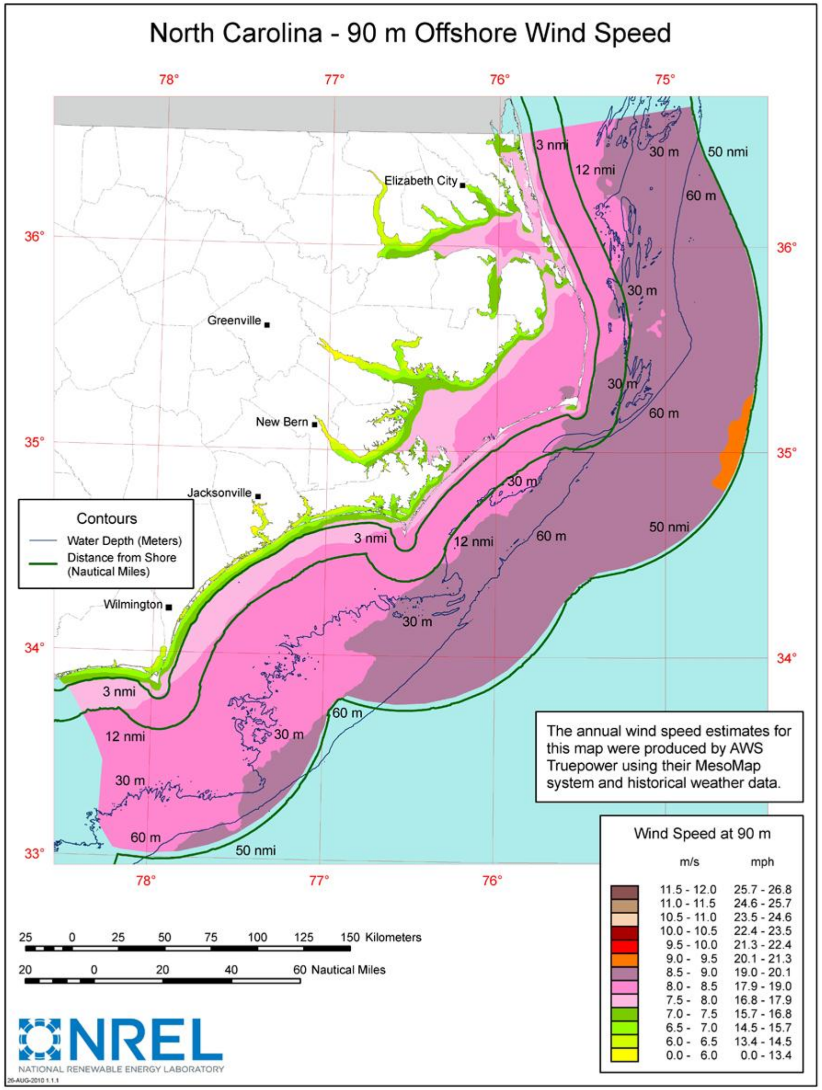
Interests in Wind Energy

- Mid Atlantic states have offshore wind.
  - Potential Economic impact is large

- Deployment of wind energy anticipated to grow rapidly
  - ~4.5% today
  - ~10% by 2020
  - ~20% by 2030
  - ~35 % by 2050

- Levelized cost decreasing
  - Land
    - 24% reduction by 2020
    - 33% reduction by 2030
    - 37% reduction by 2050
  - Offshore
    - 22% reduction by 2020
    - 43% reduction by 2030
    - 51% reduction by 2050



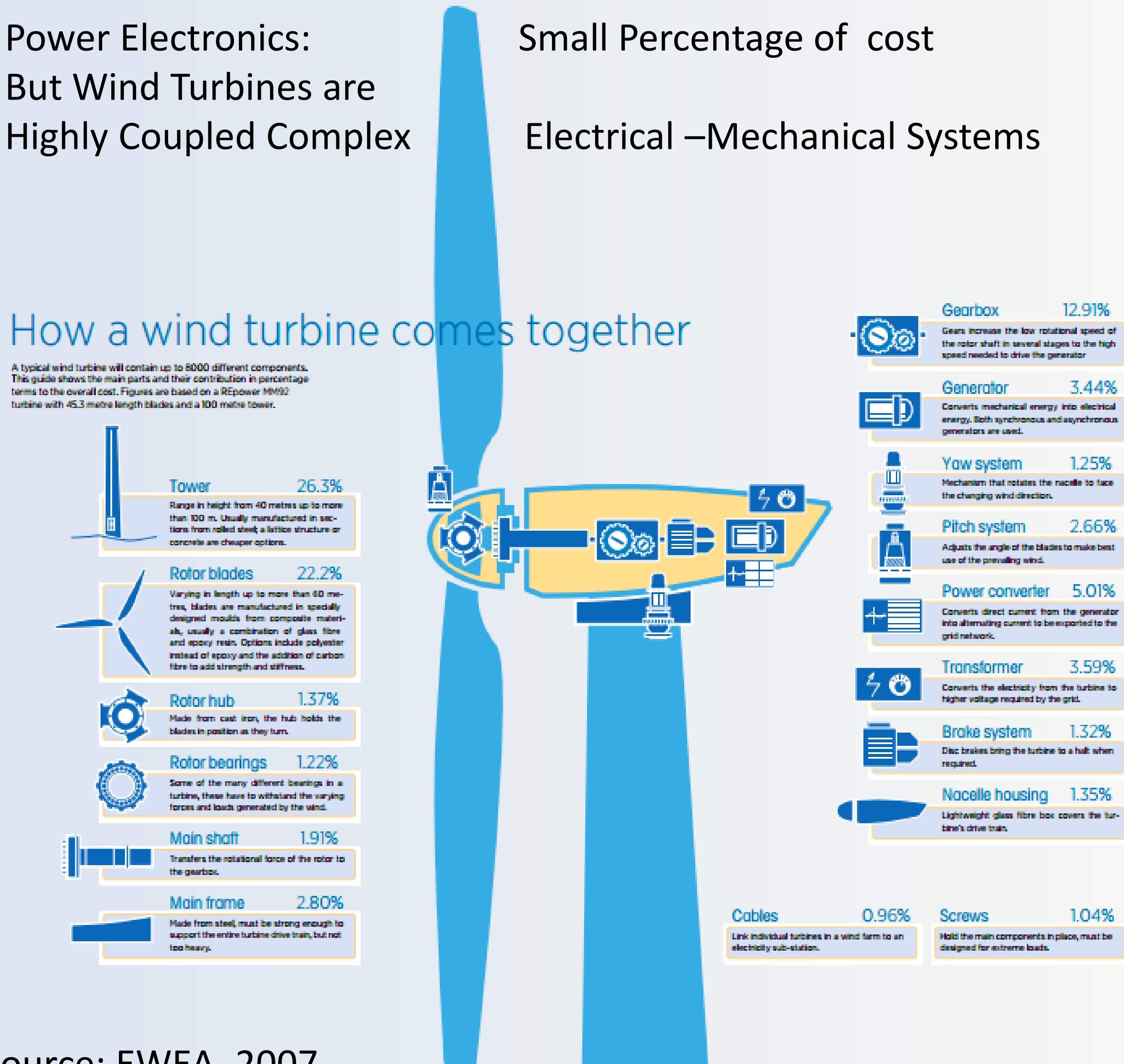
- Variability and uncertainty posed by wind power at various time scales will require innovation to connect to the Grid. ➔ Better Power Electronics

PowerAmerica — Power Electronics as a subsystem

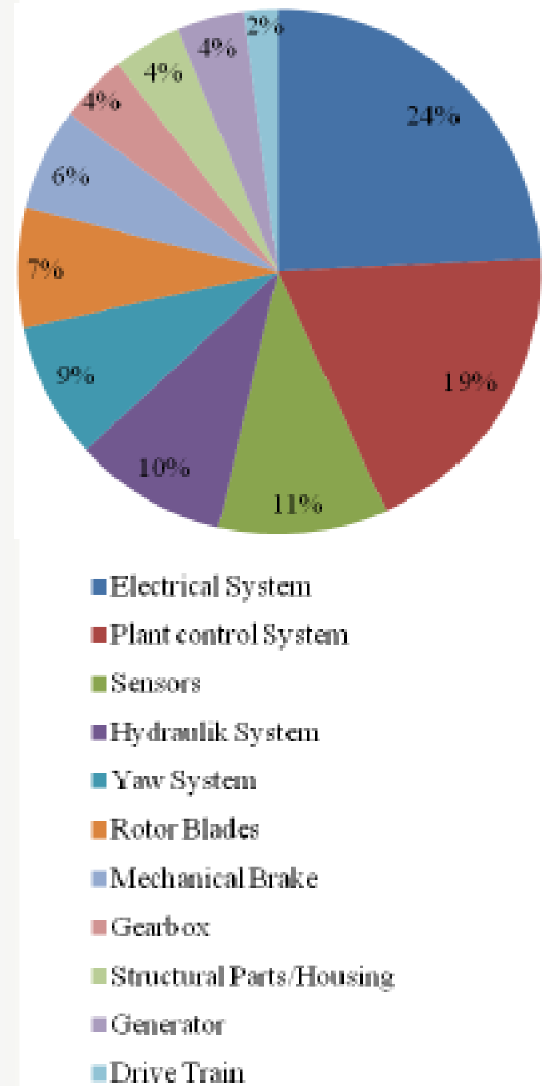
Power Electronics:
But Wind Turbines are
Highly Coupled Complex

Small Percentage of cost

Electrical –Mechanical Systems



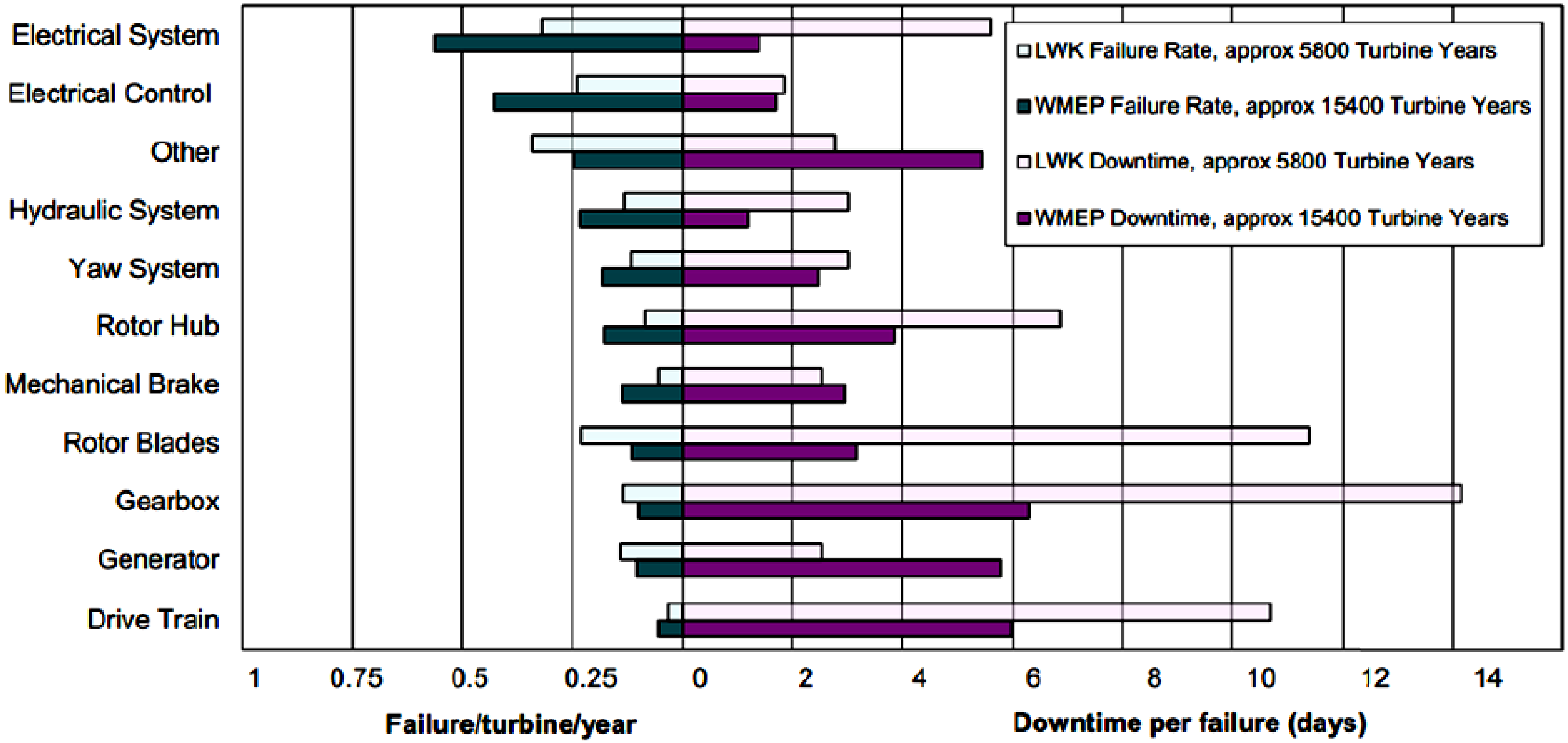
Share of the main components of the total number of failures.



Source: EWEA, 2007

Electrical Systems and Electrical Control Reliability

Figure 5. Failure rates and downtime from two large surveys of European WTs over 13 years [13]. Reprinted/Reproduced with permission from [13]. Copyright 2007, Springer Science + Business Media.



P. Tchakoua, et al. Wind Turbine Condition Monitoring: State-of-the-Art Review, New Trends, Future Challenges, Energies 2014, 7, 2595-2630; doi:10.3390/en7042595

Power Electronic Advantages of Silicon Carbide

SiC MOSFET,
Higher Efficiency,
Simpler Gate Drive,
Simpler Topologies

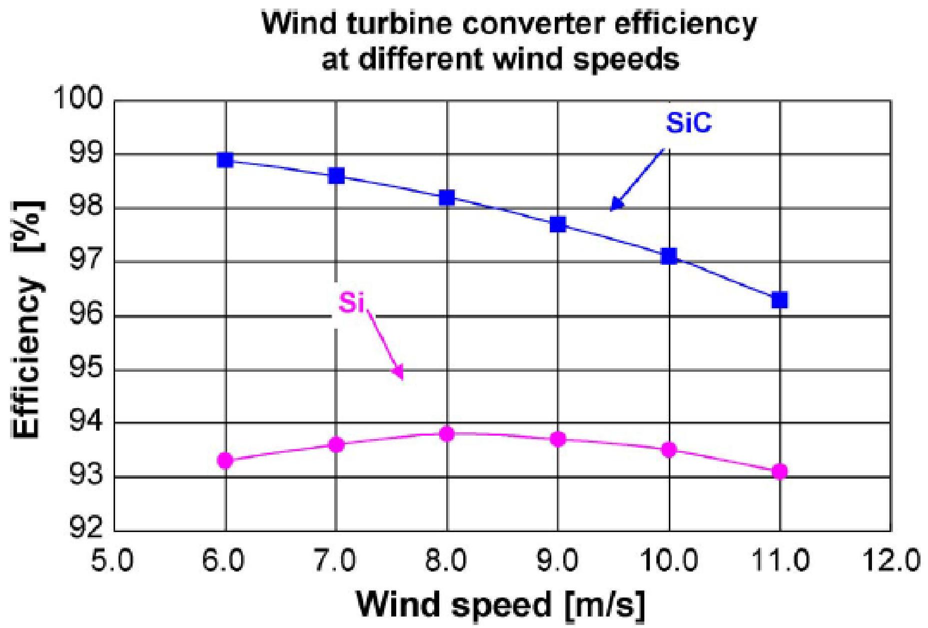


Fig. 9. Efficiency of SiC- and Si-based wind turbine converters at different wind speeds and 3 kHz switching frequency.

H. Zhang, L.M. Tolbert, Efficiency Impact of Silicon Carbide Power Electronics for Modern Wind Turbine Full Scale Frequency Converter, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 58, NO. 1, JANUARY 2011

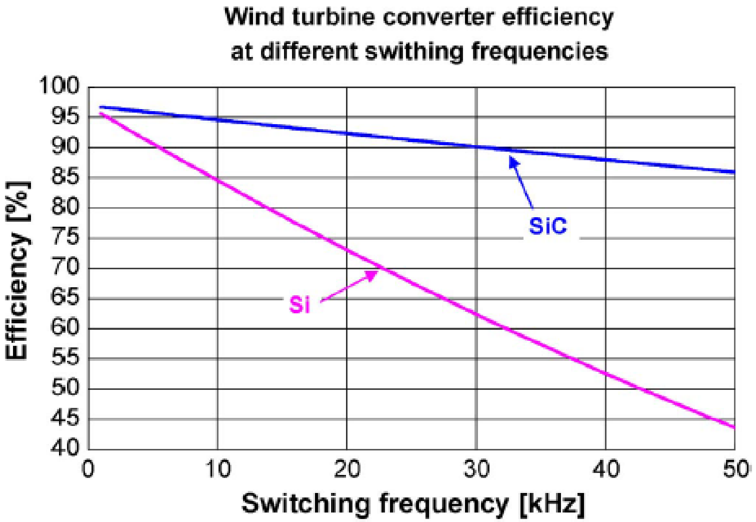


Fig. 11. Efficiency of SiC and Si wind turbine converters at full power rating and different switching frequencies.

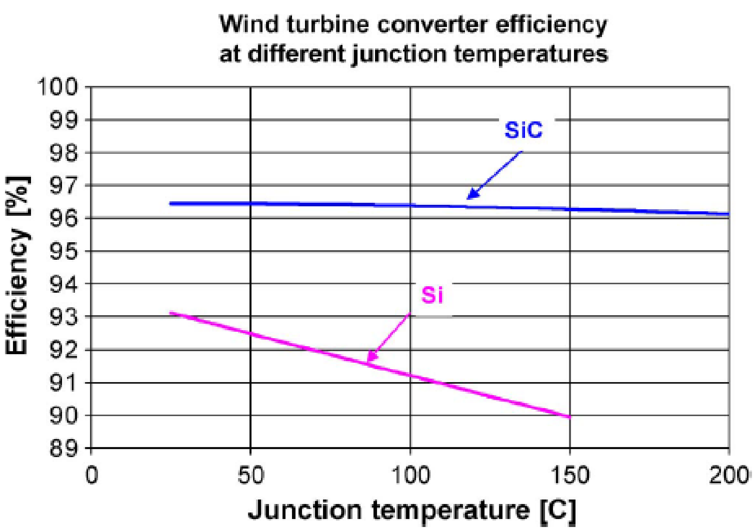
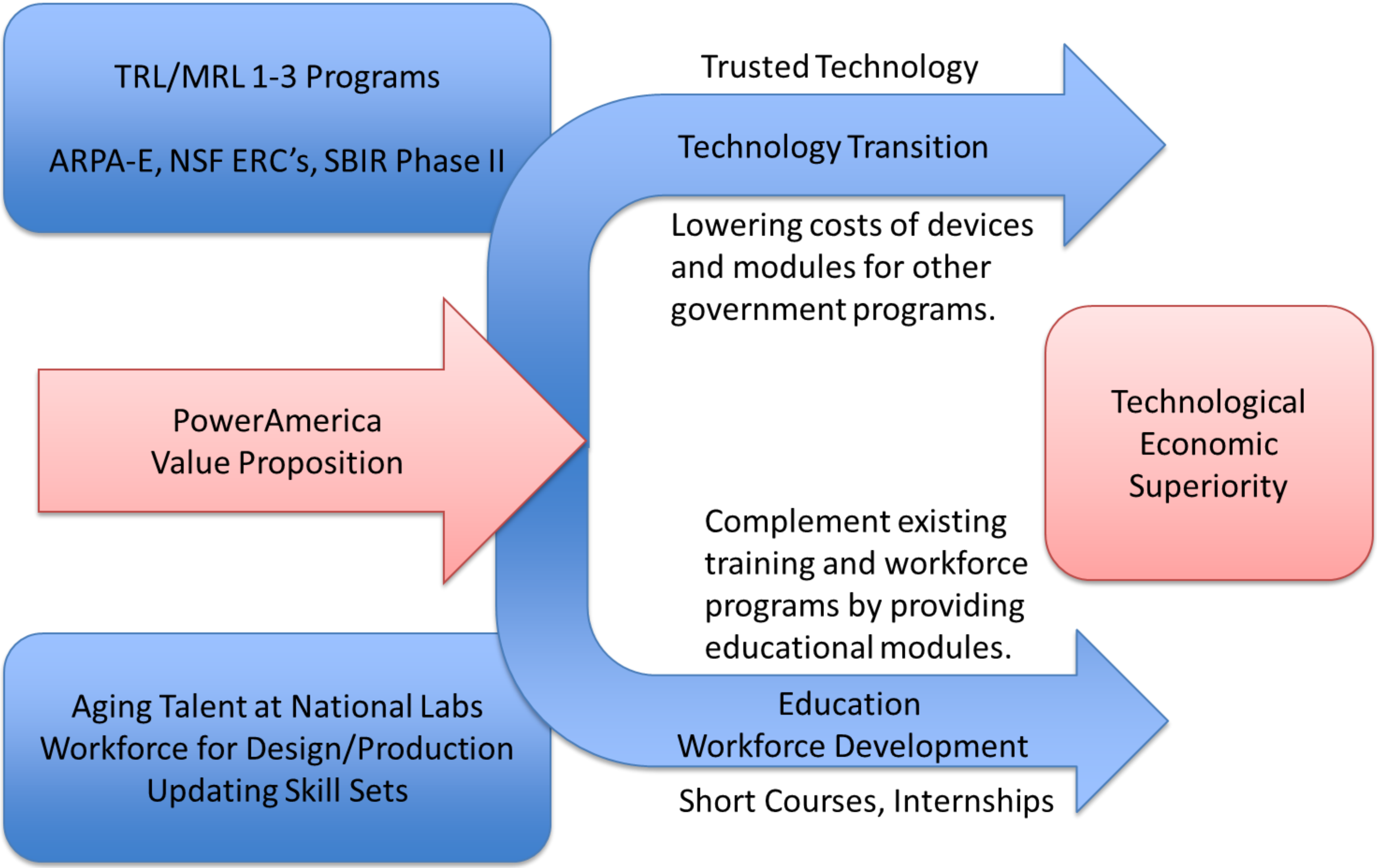
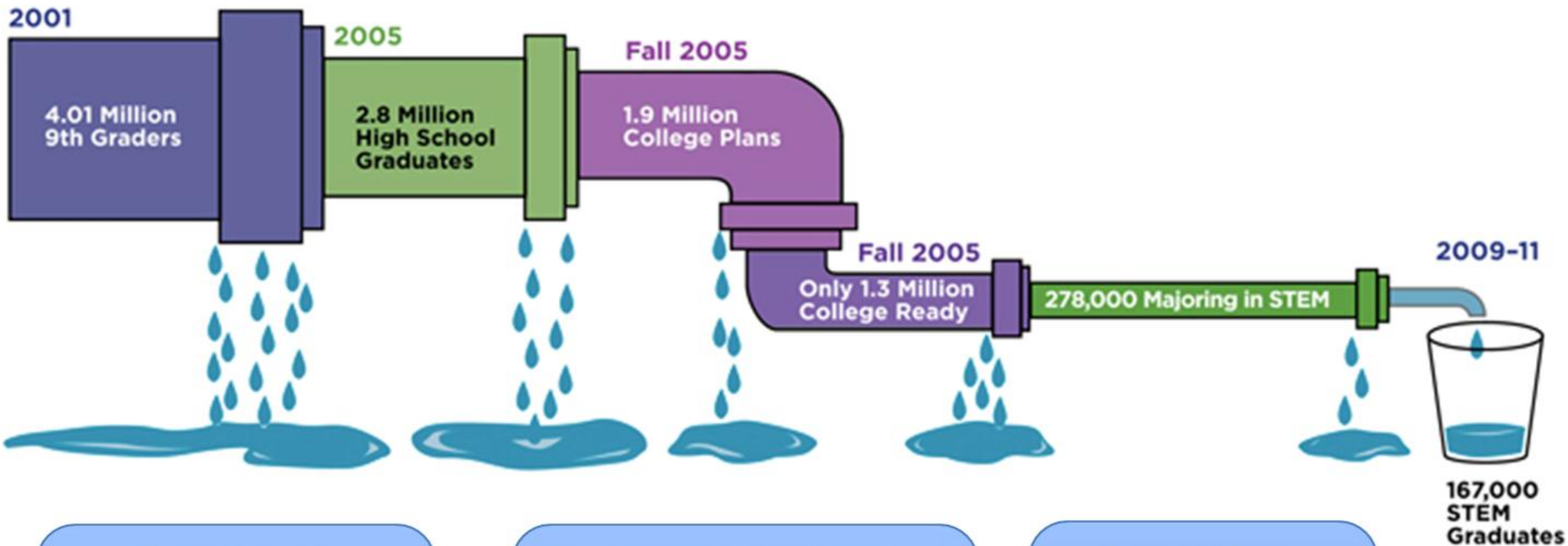


Fig. 12. Efficiency of SiC and Si wind turbine converters at full power rating and different temperatures.

Two Aspects of the PowerAmerica



Education and Workforce Pipe Line



Emphasis on Recruiting US Students

Outreach to Universities at the Freshman Year Include Disadvantage Populations.

Internships To provide vision where the Jobs are!

Leverage other programs:
MEP, ATE, eCyberMission, SMART, NSDEG, etc.

POWERAMERICA

A Strong Workforce and Education Program

Universities

- Pipeline to M.S and PhD
- WBG M.S. Concentration
- Web Portal Distance Education
- Train the Trainer Community College
- Short Courses

Government

- DoE/DOD National Lab Internships

NIST

- Manufacturing Extension Partnerships

NSF

- Advanced Technology Education

Industry

- Internships
- Scholarships
- Sponsor Capstone Projects
- Contribute to Short Courses, STEM outreach
- Jobs

MS in Electric Power Systems Engineering-
Professional Science Masters

Goal: Comprehensive training for a career in power industry

- Sponsor: DOE, Workforce for Electric Power Sector
- Started: Summer 2011 with 7 students, FA14: 39
- Graduates: 34
- New Courses: Comm & SCADA, Smart Dist. Sys.
- Professional Skills Comp: Utility Business, Practicum, Capstone
- Strong support from Industry:

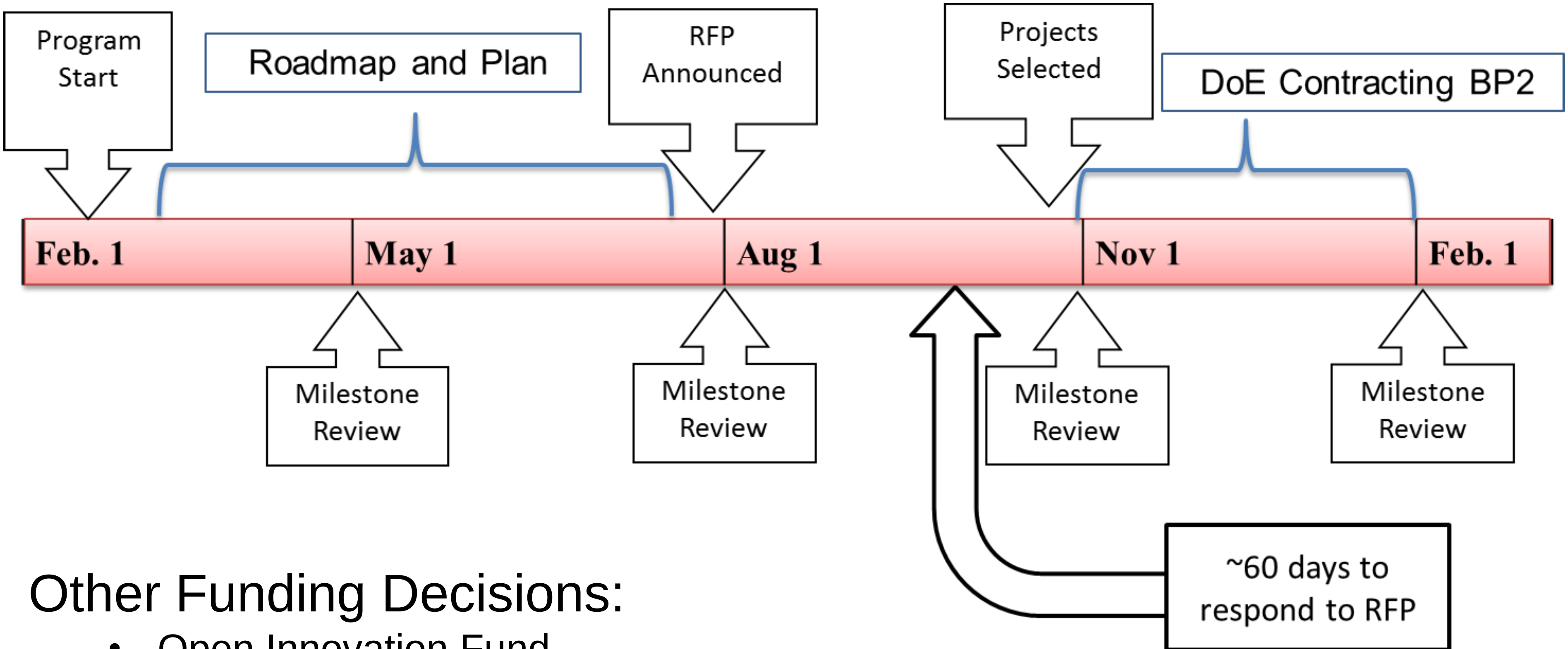
  6 Fellowships

Master of Science (MS) in WBG Power Electronics 12 month Program

The MS in WBG Power Electronics is proposed to initially be a track under the umbrella of the MS in Electric Power Systems Engineering program since the PSM review process may take up to two years. T he Track will require an internal review through NCSU, which will permit the program to start a cohort earlier.

Course Area	Course	Credits	Semester
Introduction Course	Manufacturing Systems (Required)	3	First
Introduction Course	Lean Six Sigma (Required)	3	First
Power Electronics (534)	Power Electronics with Lab (Required)	4	First
Devices	WBG Power Devices with labs in SiC Power device lab and GaN lab (Required)	4	Second
Capstone Project	WBG PE Capstone Project (Design and Project Management) Required	3	Second
Packaging	Power Electronics Packaging with lab (Required)	4	Third
Capstone Practicum	WBG PE Capstone Practicum (Required)	3	Third
Elective	Advanced Power Electronics	3	Second or Third
Elective	Electric Motor Drives	3	May be taken any semester
Elective	Heat Transfer Theory and Applications	3	May be taken any semester
Elective	Product Innovation WBG Semiconductors	3	Spring
Elective	Supply Chain	3	May be taken any semester

Time Line For Annual DoE Funding



Other Funding Decisions:

- Open Innovation Fund
- Small Projects From Membership Fees
- Educational and Student Projects


• $1 billion invested
• 4 million sq. ft.
• 66 partners
• 4th largest engineering college
NC State's Centennial Campus

Existing Infrastructure at NC State

POWERAMERICA

CREE

RFMD

THE RESEARCH TRIANGLE PARK

RESEARCH TRIANGLE CLEANTECH CLUSTER

NC Sustainable Energy Association

NC State's Centennial Campus

NCSU Nanofabrication Facility

Analytical Instrumentation Facility