IEA Technology Collaboration Programme
on Energy Efficient End-Use Equipment

Power Electronic Conversion
Technology Platform PECTA

New power electronics to reach next level of energy efficiency in equipment

Results from the IEA 4E PECTA platform's first term

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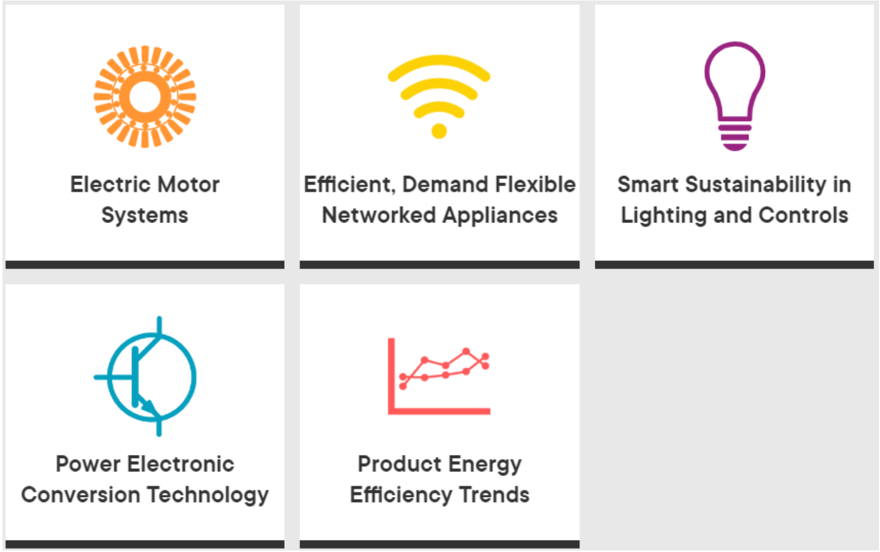
Content

- **Introduction to IEA 4E Power Electronic Conversion Technology Platform**
- **Wide Band Gap (WBG) technologies**
  - Evaluation of energy saving potentials
  - Assessing environmental impacts of WBG
  - Barriers for WBG adoption
  - Standardization and policy measures to support WBG adoption
- **Application Readiness Maps (ARMs)**
- **Future work**

Members of 4E

- IEA Technology Collaboration Program 4E (Energy Efficient End use Equipment)
- 15 Countries from the Asia-Pacific, Europe and North America area
  - *Australia, Japan, South Korea, China, Sweden, Denmark, UK, France, Austria, Switzerland, Canada, USA, The Netherlands, New Zealand, EU Commission*

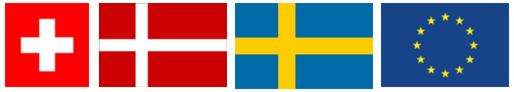


Organization of 4E

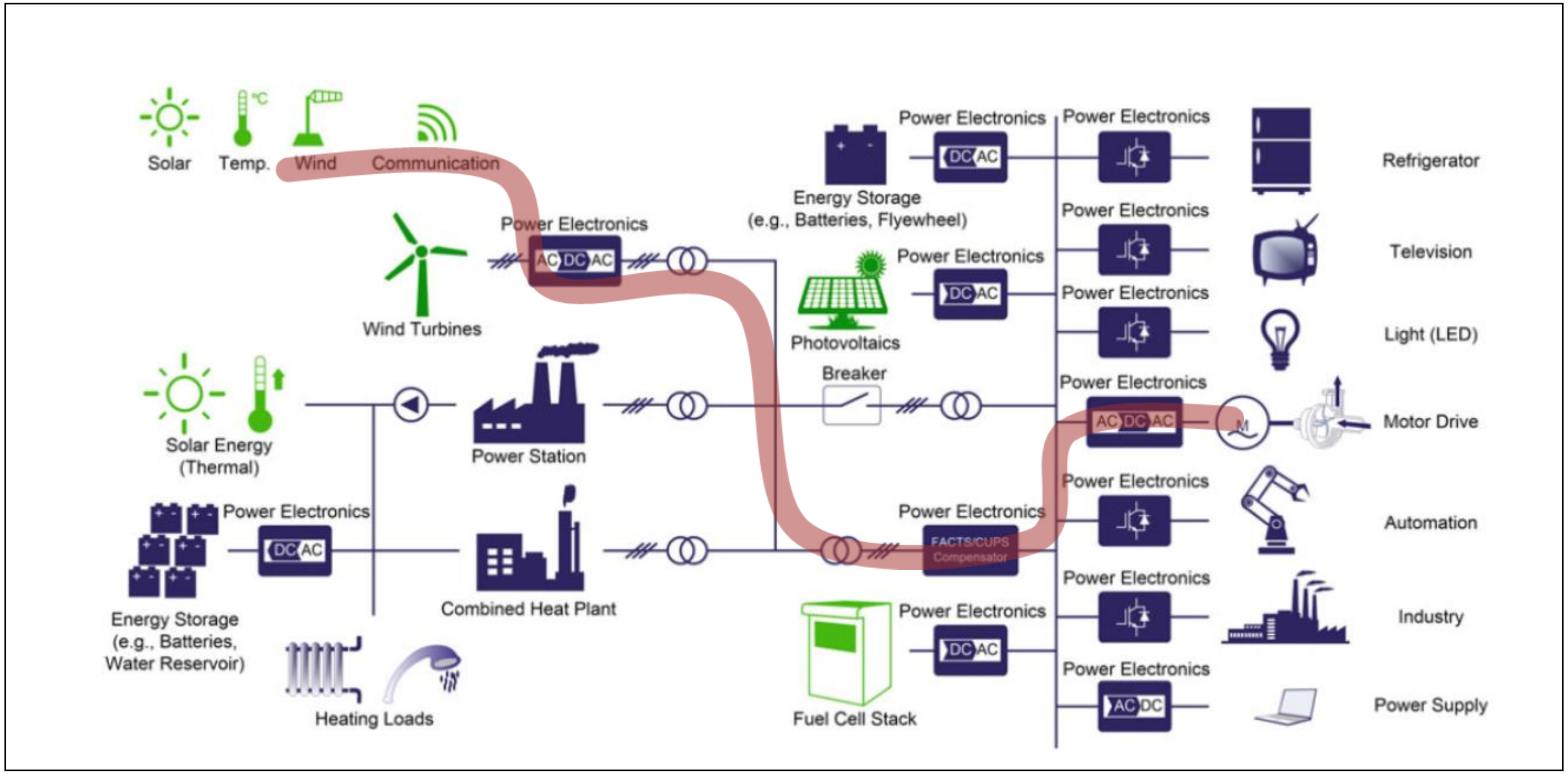
- Platforms and projects
- Periodical meetings for information exchange and management issues
- Monthly Management Committee TELCOs

PECTA

- Focuses on energy efficient Wide Band Gap (WBG) technology
- Serves as a bridge between Academia, Industry and Policy makers



Power electronics is everywhere, and its efficiency is relevant!



Production | Transmission/Distribution/Storage | End use equipment

PECTA achievements - Selected final reports and papers

- Makoschitz M., Krischan K., Bergmann P., Díaz A. and Brueniger R. **Wide Band Gap Technology: Efficiency Potential and Application Readiness Map**, 4E Power Electronic Conversion Technology Annex (PECTA), May 2020.
- Spejo L. B., Nonis E., Schulz N., Minamisawa R. A., Makoschitz M. **Energy saving potential of WBG-commercial power converters in different applications**, 4E Power Electronic Conversion Technology Annex (PECTA), October 2023.
- Machtinger K., Zhu H., Makoschitz M., Matioli E., Brueniger R. **Energy Efficiency Measurement of Wide Bandgap Based Power Supplies**, 4E Power Electronic Conversion Technology Annex (PECTA), January 2024.
- Eskilson T., Jehle A., Schmidt P., Makoschitz M., Baumgartner F. **Identifying the potential of SiC technology for PV inverters**. Conference paper for PECTA-sessions at EPE'23, Aalborg, Denmark, September 2023.
- Glaser S., Feuchter P., Pamminger R., Díaz A. **Wide Band Gap Technology: Energy and environmental related Life Cycle Assessment (LCA)**. 4E Power Electronic Conversion Technology Annex (PECTA), October 2023.
- Hansen B. S. **Wide Band Gap Technology: Timing of most beneficial policy measures**, 4E Power Electronic Conversion Technology Platform, May 2024.
- Iannuzzo F., Zhang K. **Reliability of electronic components and systems with WBG technology**, 4E Power Electronic Conversion Technology Platform (PECTA), October 2023.
- Zhu H., Perera N., Jafari A., Matioli E. **Analysis and Loss Measurements of WBG-Based Devices**, 4E Power Electronic Conversion Technology Annex (PECTA), December 2023.
- Thoben M., Pfost M. **Application Readiness Map for Wide Band Gap (WBG) Semiconductors**, 4E Power Electronic Conversion Technology Annex (PECTA), December 2023

Wide Band Gap (WBG) technologies

- Wide Band Gap (WBG) technologies, which include materials like silicon carbide (SiC) and gallium nitride (GaN), are pivotal for developing next-generation power electronic devices due to their superior electrical properties compared to traditional silicon-based technologies.
- The main advantages can be summarized as follows:
- Higher efficiency
- Higher operating temperatures
- Faster switching frequencies
- Higher breakdown voltage
- Reduced system size and weight
- Improved thermal conductivity

Evaluation of energy saving potentials

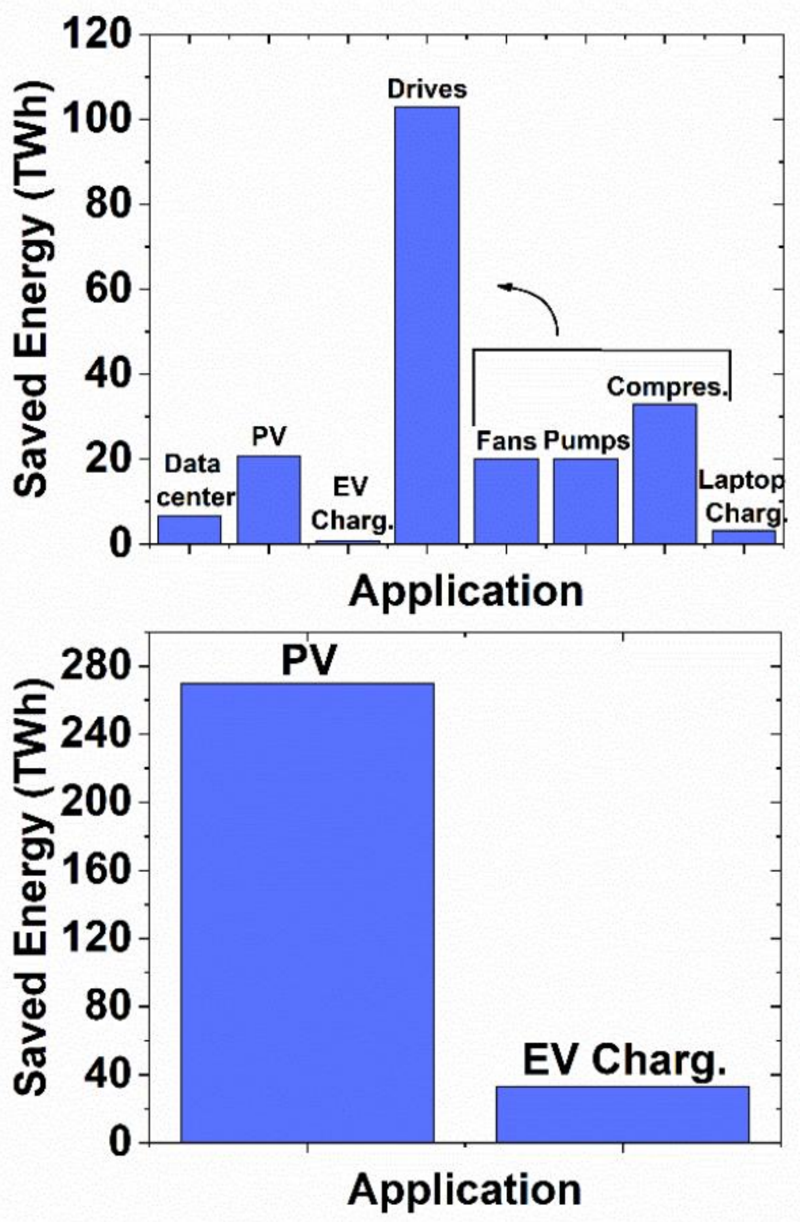
Methodology:

1. Gathering data on the yearly global energy consumption for selected applications
2. Research of efficiencies of existing silicon-based and WBG-based systems were through product datasheets and scientific literature
3. Global yearly energy saving potential was calculated based on the efficiency differences between silicon and WBG products, factoring in the global annual energy consumption per application, and typical application profiles where possible

Estimated saving potential (2021):

- **> 120 TWh**, Twice the annual electric energy demand of Switzerland

Strong future growth for some applications (2050)



Measuring the energy efficiency of WBG

Test case: 7 power supplies with different power ratings ranging from 5W to 65W

- For power levels up to 30W, the Si-based and GaN-based chargers showed similar energy efficiency performances of around 90% at rated power.
- For higher power levels above 30W, the GaN-based power supplies outperformed the Si-based ones. For example, at 60W, the average efficiency was 92% for GaN and 90% for Si.

Test case: Commercial Si IGBT-based photovoltaic (PV) inverter vs SiC MOSFET inverter

- WBG reducing semiconductor losses - over 50% reduction compared to IGBTs in some scenarios
- SiC MOSFETs provided efficiency improvements, especially at higher power levels and lower input voltages, resulting in annual efficiency gain estimated up to 2.66% (under Austrian conditions)

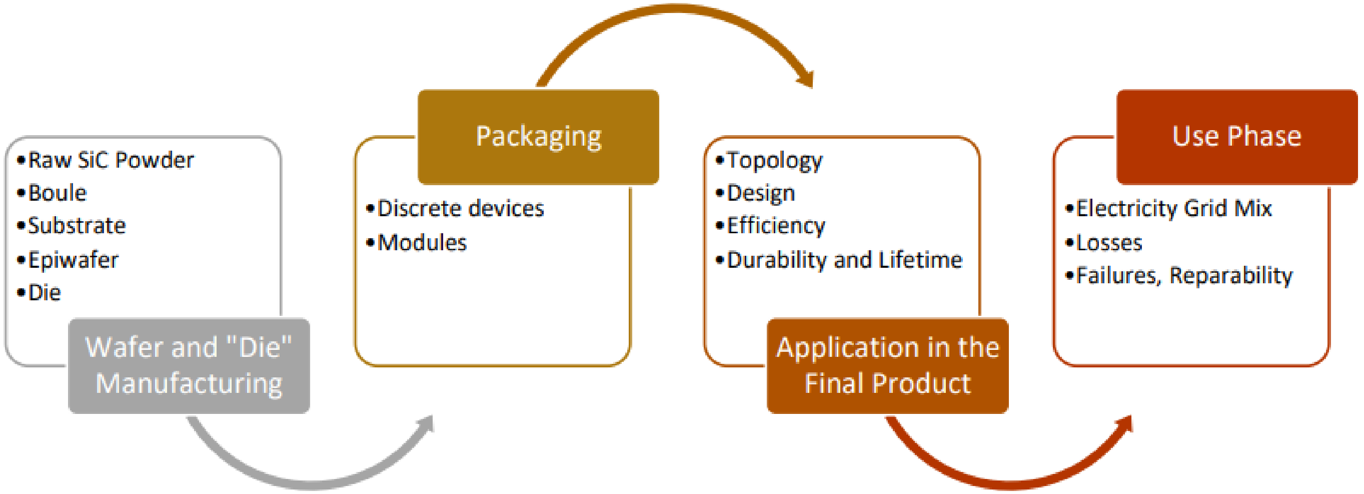
Assessing environmental impacts of WBG

Research focused on three areas:

1. Manufacture of WBG devices
2. Design aspects and environmental impacts
3. WBG resources and End-of-Life (EoL) perspectives

Manufacture of WBG devices

- SiC manufacturer compared to Si currently more energy intensive in manufacturing
- Can potentially be offset by increased energy efficiency during the use phase (e.g. SiC PV inverter)
- Justify evaluating the impacts holistically across all life cycle stages
- Lack of up-to-date, publicly available life cycle assessments (LCAs) for power semiconductors and WBG technologies



Assessing environmental impacts of WBG

Design aspects and environmental impacts

Case study: The effects of incorporating WBG semiconductors

Left: 60W Si-based laptop charger (reference)

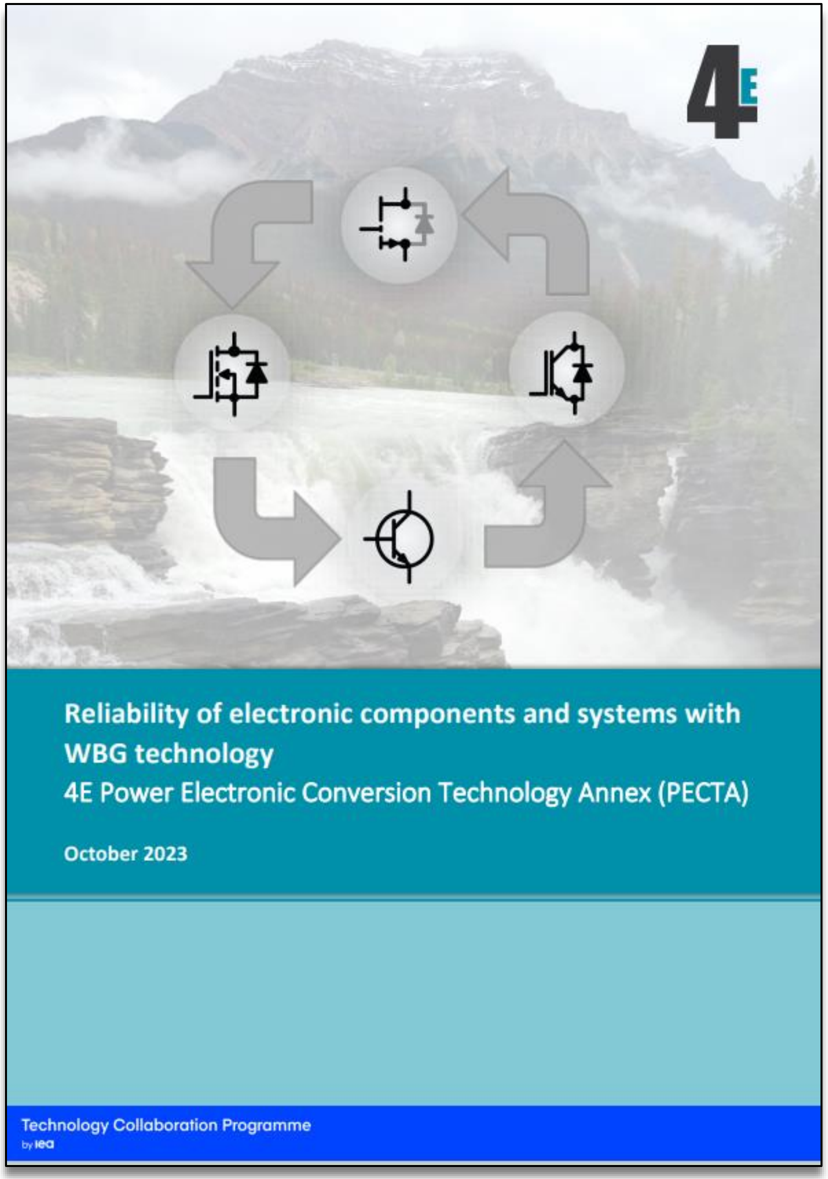
Right: 60W GaN-based laptop charger

- The smaller chip size enabled by WBG materials. For the GaN laptop charger case study, die size was around 58% smaller compared to the silicon reference charger.
- Using WBG allows for higher switching frequencies, enabling smaller passive components like transformers and filters.
- The charger size was reduced by around 30% with GaN.

Barriers for WBG adoption

Important barriers identified include:

- Cost and manufacturing challenges
- Reliability concerns
- Lack of standardized components/platforms
- Knowledge gaps on design
- High voltage/high current challenges
- Cost pressure in some markets



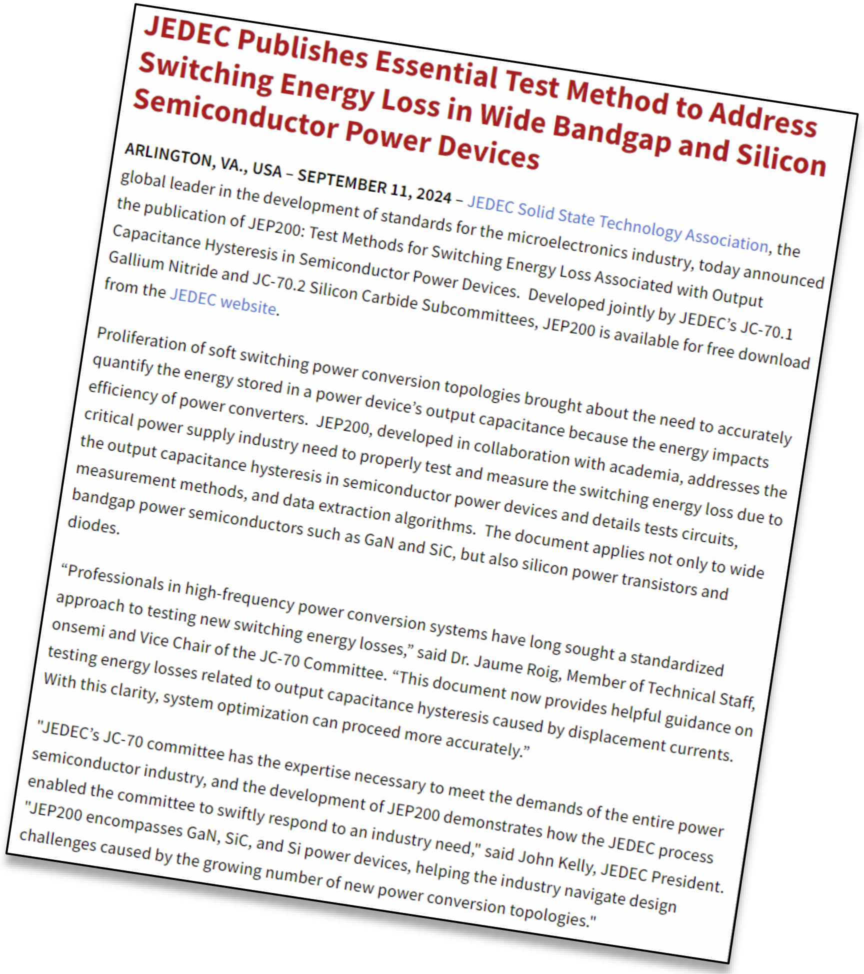
Standardization and policy measures to support WBG adoption

Policy measures explored:

- Product energy efficiency regulations (no exist for WBG)
- Standards and testing methods

Standardization needs identified:

- Harmonized and robust reliability and durability test methodologies
- Product Category Rules to support the evaluation of the environmental aspects and impacts of WBG.
- Energy efficiency test methodologies (JEDEC)
- Specific product architectures of power modules and systems to gain the full benefit from WBG components



JEDEC Publishes Essential Test Method to Address Switching Energy Loss in Wide Bandgap and Silicon Semiconductor Power Devices

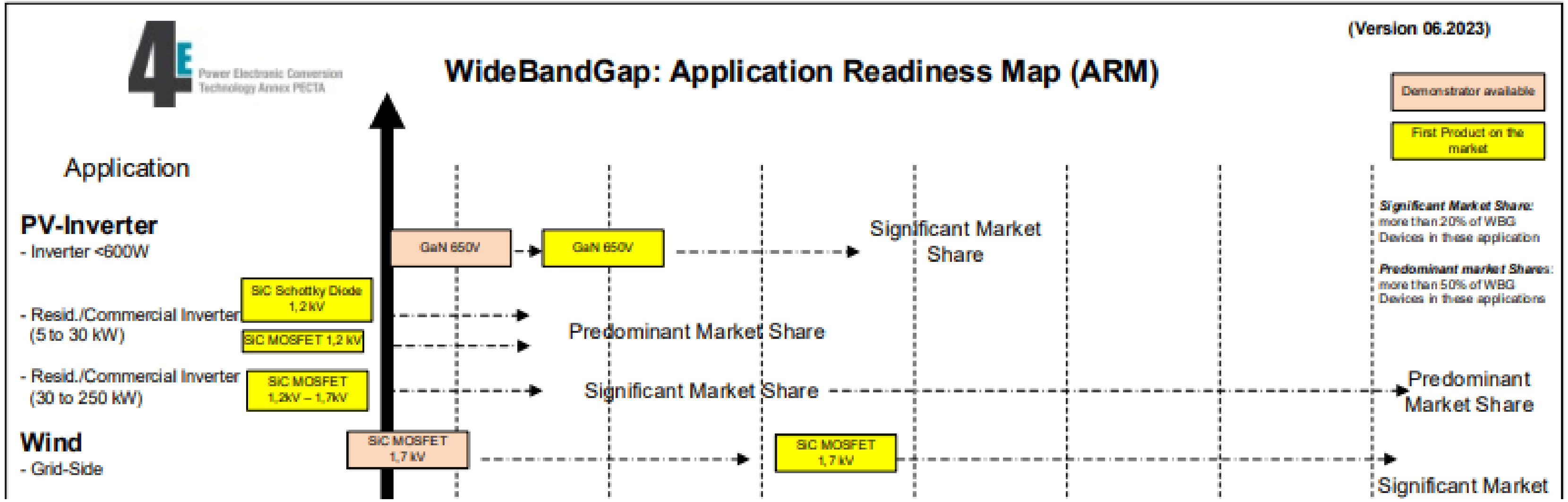
ARLINGTON, VA., USA – SEPTEMBER 11, 2024 – JEDEC Solid State Technology Association, the global leader in the development of standards for the microelectronics industry, today announced the publication of JEP200: Test Methods for Switching Energy Loss Associated with Output Capacitance Hysteresis in Semiconductor Power Devices. Developed jointly by JEDEC's JC-70.1 Gallium Nitride and JC-70.2 Silicon Carbide Subcommittees, JEP200 is available for free download from the JEDEC website.

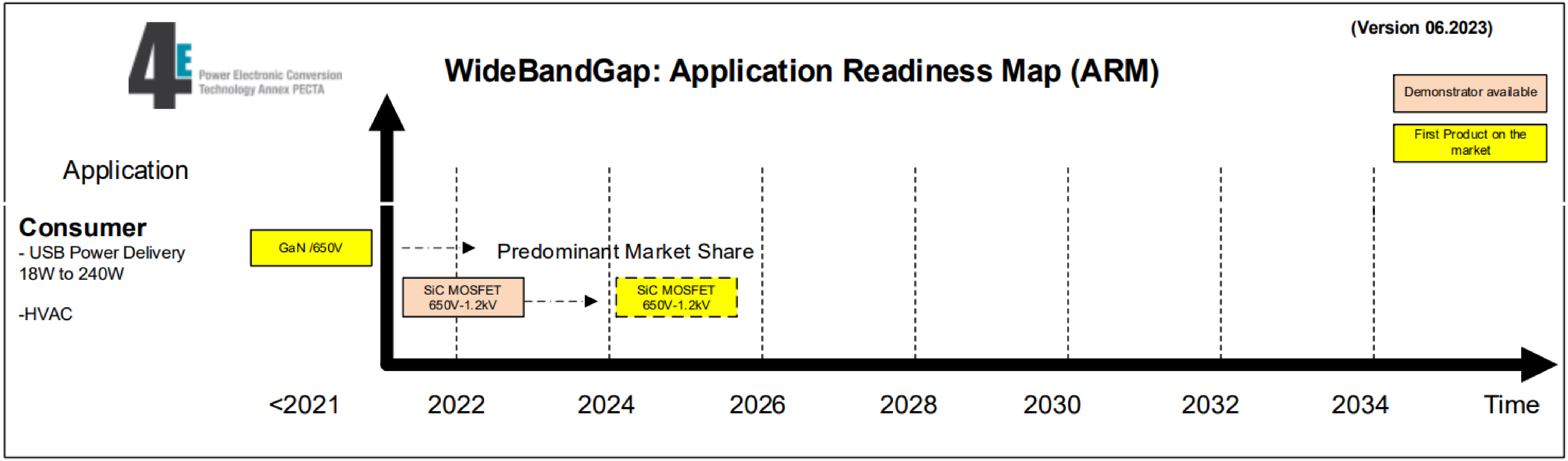
Proliferation of soft switching power conversion topologies brought about the need to accurately quantify the energy stored in a power device's output capacitance because the energy impacts efficiency of power converters. JEP200, developed in collaboration with academia, addresses the critical power supply industry need to properly test and measure the switching energy loss due to the output capacitance hysteresis in semiconductor power devices and details tests circuits, measurement methods, and data extraction algorithms. The document applies not only to wide bandgap power semiconductors such as GaN and SiC, but also silicon power transistors and diodes.

"Professionals in high-frequency power conversion systems have long sought a standardized approach to testing new switching energy losses," said Dr. Jaume Roig, Member of Technical Staff, onsemi and Vice Chair of the JC-70 Committee. "This document now provides helpful guidance on testing energy losses related to output capacitance hysteresis caused by displacement currents. With this clarity, system optimization can proceed more accurately."

"JEDEC's JC-70 committee has the expertise necessary to meet the demands of the entire power semiconductor industry, and the development of JEP200 demonstrates how the JEDEC process enabled the committee to swiftly respond to an industry need," said John Kelly, JEDEC President. "JEP200 encompasses GaN, SiC, and Si power devices, helping the industry navigate design challenges caused by the growing number of new power conversion topologies."

Application Readiness Maps (ARMs)





Future work – 2024-2029

1. Policy research and policy tools

- 1.1 Finetuning of promising policy measures for particular appliances/equipment
- 1.2 Improving EU regulation on PV converters
- 1.3 Identify possible policy approaches for WBG based efficiency improvement for motors and motorsystem
- 1.4 Efficiency measurement standards

2. Policy supporting activities

- 2.1 Revision and update of Aplication Readiness Map ARM
- 2.2 GHG emission and sustainable use of resources
- 2.3 E-Vehicle Chargers
- 2.4 Measurement of particular appliances and equipment
- 2.5 Use cases / product reliablity

3. Industrial coordination and cooperation

- 2.1 Technology drivers / Trendsetters
- 2.2 Industrial Bridge
  → Activity-Leader:
  R. Brüniger, M. Makoschitz

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ECPE

- Industrial Bridge ECPE-PECTA

→ ECPE Leader: Leo Lorenz
→ Deputy: Thomas Harder

4. Dissemination / Communication

- 4.1 Workshops
- 4.2 Lecturers at Universities
- 4.3 Reports and Policy Briefs
- 4.4 Large PECTA's end-term event

Get involved

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