IEA Technology Collaboration Programme
on Energy Efficient End-Use Equipment

Power Electronic Conversion
Technology Annex PECTA

# Wide Band Gap Semiconductors – the future of power electronics

## (based on PECTA – the Power Electronic Conversion Annex of the IEA TCP 4E)

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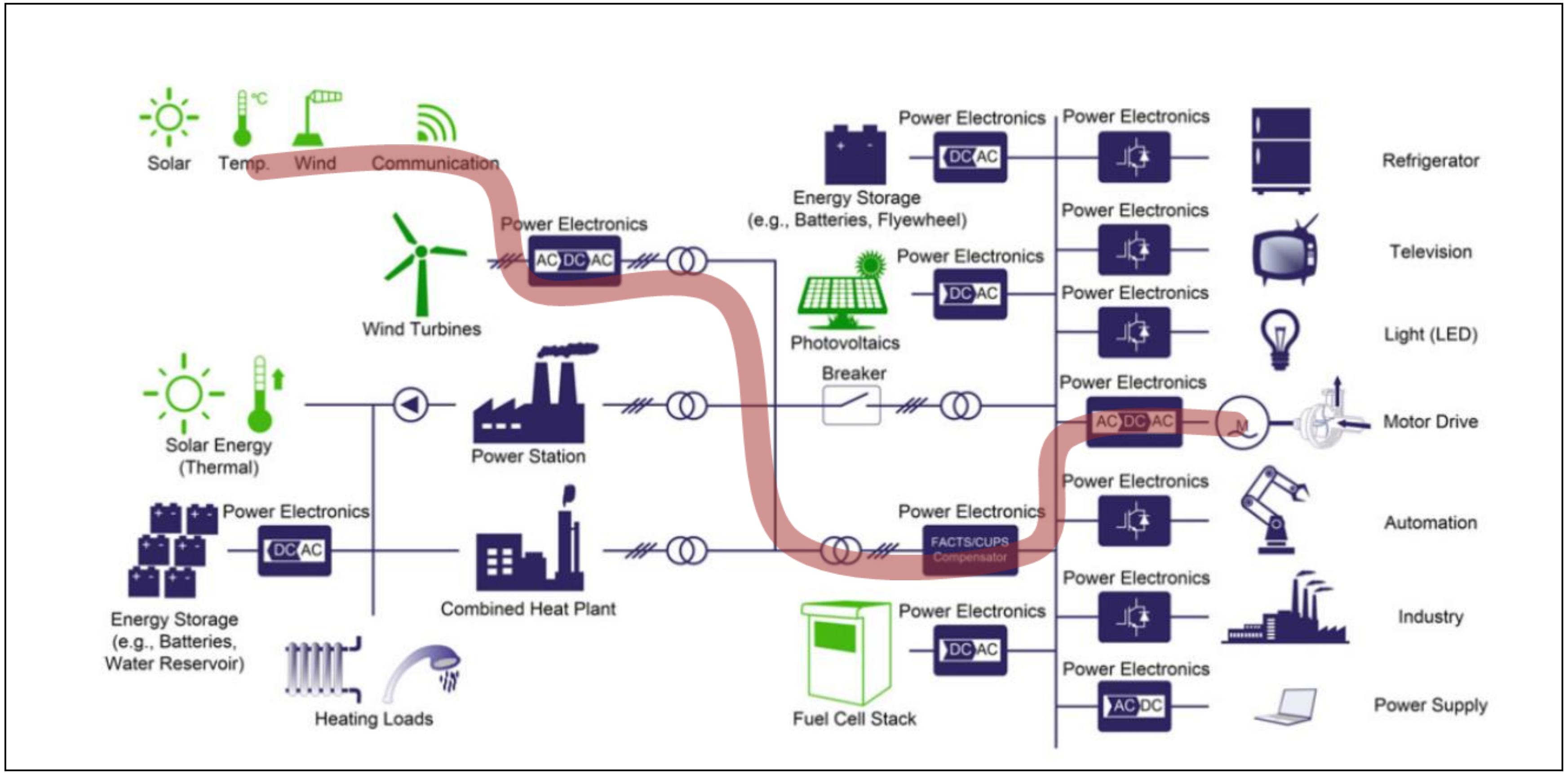
iea-4e.org

## International Context (IEA-TCP)

- **4E: Energy Efficient End-Use Equipment**
- **14 Countries and the EU-Commission** are currently member of the 4E TCP (Countries: AU, AT, CA, CN, DK, FR, JP, KR, NL, NZ, CH, SE, UK, US)
- 4 ongoing Annexes:
  - EMSA: Electric Motor Systems Annex
  - EDNA: Electronic Devices and Networks Annex
  - SSL: Solid State Lighting Annex
  - PECTA: Power Electronic Conversion Technology Annex
- 2 major initiatives:
  - PEET: Product Energy Efficiency Trends
  - cda: Connected Device Alliance
- **Link**: https://www.iea-4e.org/

## **Technical context:** Power Electronic is everywhere and efficiency is most relevant




Production | Transmission/Distribution/Storage | End Use Equipment

## PECTA – available results

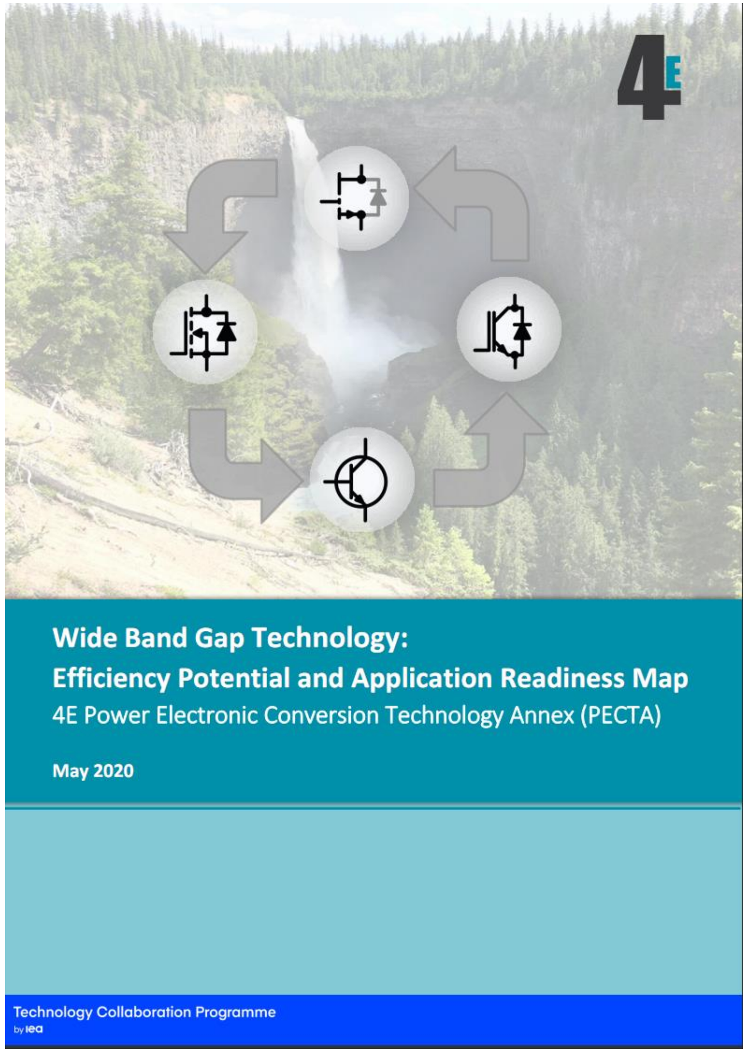
- **Publication**

  Wide Band Gap Technology:

  Efficiency Potential and Application Readiness Map

  Officially released: May 2020, 100 pages

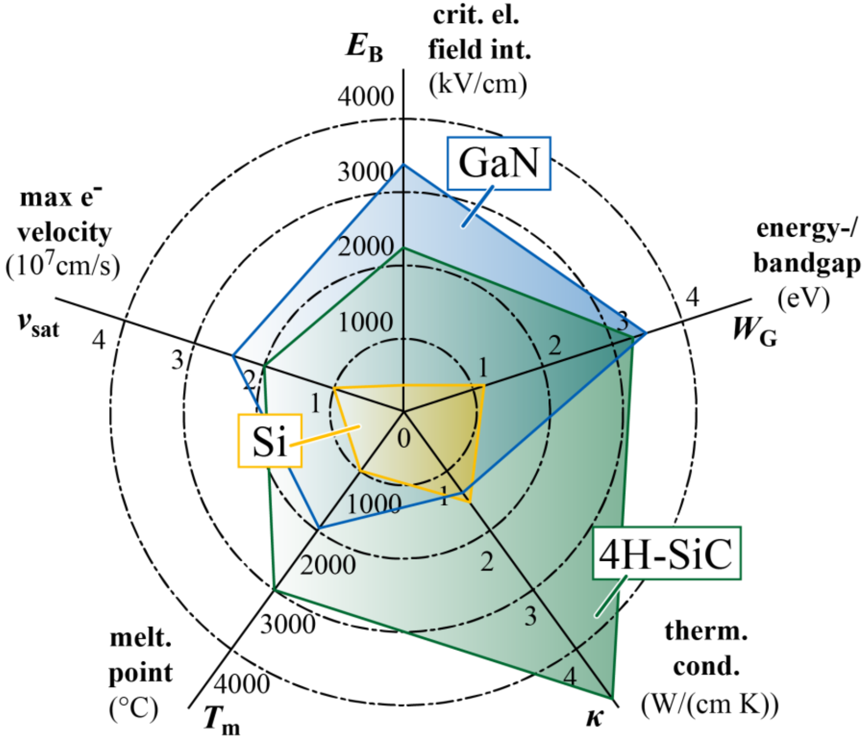
- **Outline**
  - Introduction
  - Applications in Focus
  - Advantages of WBG in the Applications
  - Existing Roadmaps
  - Application Readiness Map
  - WBG-Technology Challenges
  - Potential Energy Savings for Selected Applications
  - Exploring Policies for WBG Technology
  - Key Findings and Outlook




https://www.aramis.admin.ch/Default?DocumentID=65690&Load=true

# PECTA – available results

- **Wide Bandgap – An Overview (SiC- and GaN-based semiconductors)**

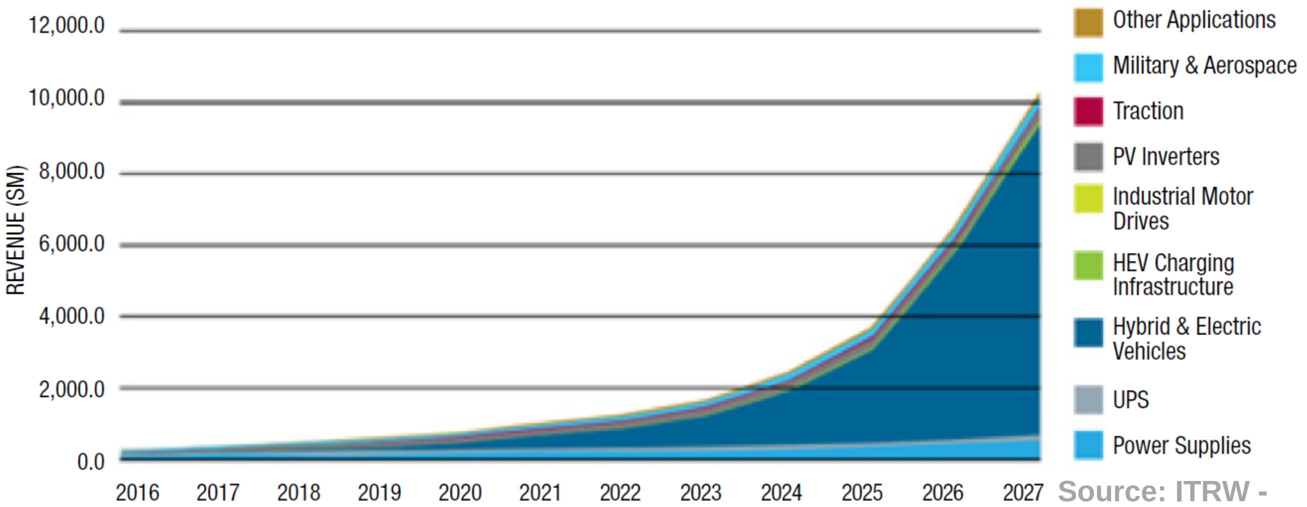



- Higher system **efficiency**
- Improved **power density**
- Faster **system response**
- Increased **blocking voltage capability**
- Suitable for **low-, medium- and high-power systems**
- **$CO_2$ reduction**

## PECTA – available results

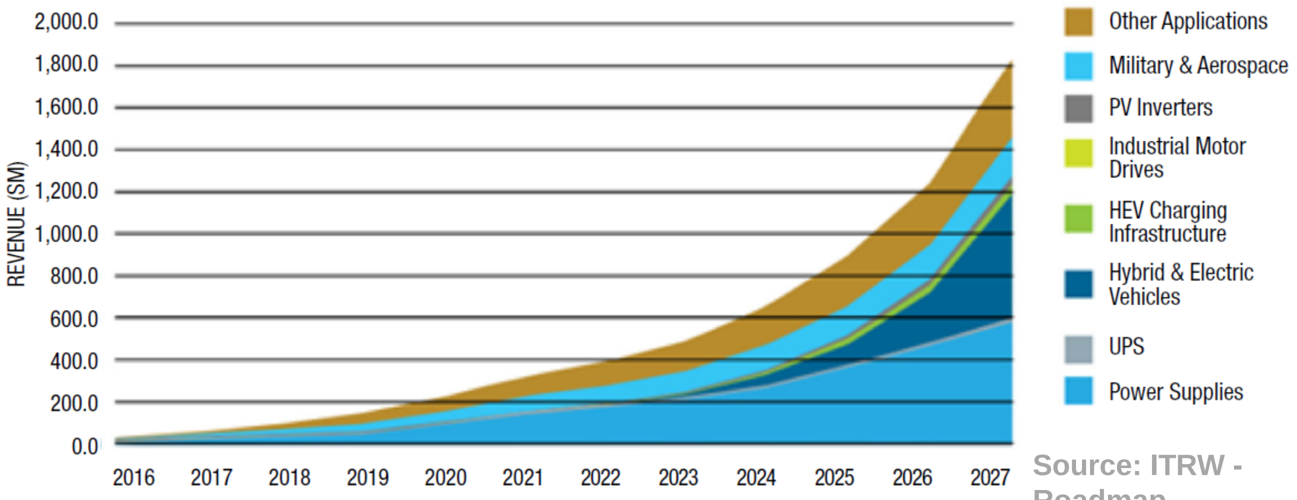
- **Market prediction – SiC:**
  - **C**ompound **a**nnual **g**rowth **r**ate (CAGR) 31% - (2018-2023)
  - According to Yole: Transistors will be key drivers
  - Automotive main driver for SiC Market (traction inverters, on-board chargers, charging infrastructure,…)
- **Market prediction – GaN:**
  - CAGR 55% - (2018-2023)
  - Power supplies are short-term drivers
  - Long-term: EVs, motor drives, wireless charging,…

THE SIC POWER CONDUCTOR MARKET




Source: ITRW - Roadmap

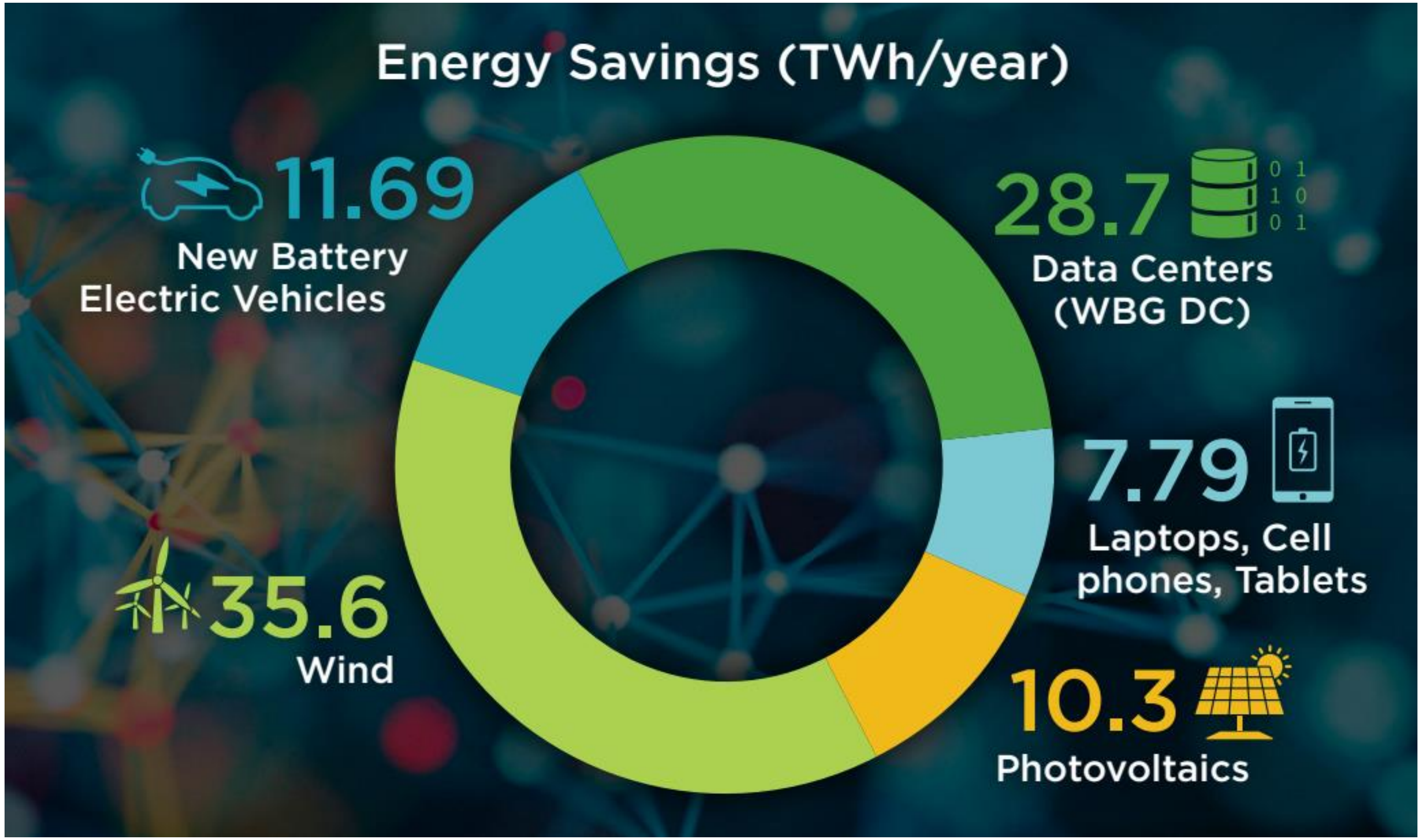
THE GAN SEMICONDUCTOR MARKET




Source: ITRW - Roadmap

## PECTA – available results

- **Energy Savings of selected applications**

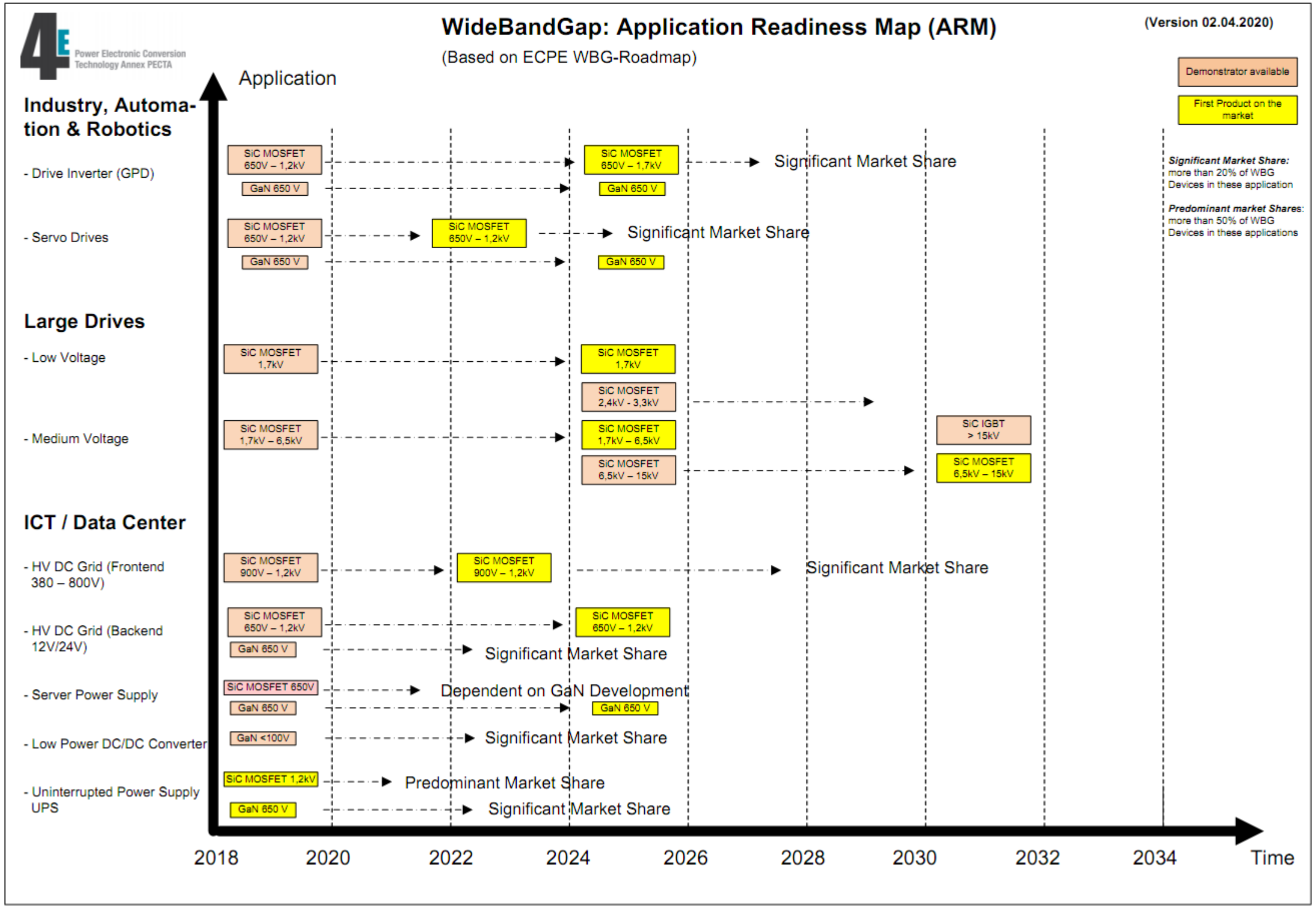


## PECTA – available results

- **Application Readiness Map (ARM)**

- This ARM was as well the basis for an ARM in the HST-TCP

→ *Indirect interaction between TCPS via CH-Representative*



# PECTA – available results

- **Policy**
  - Listing of different types and sub-types of instruments
  - WBG still at a very early stage for many applications (currently RD&D

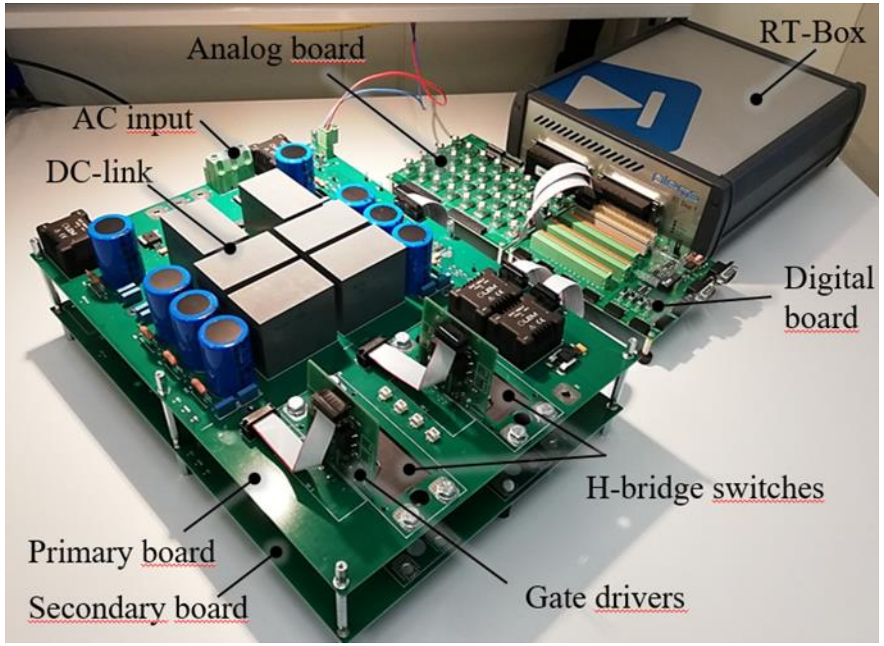
| Main Type | | Sub Type 1 | | Sub type 2 | |
|---|---|---|---|---|---|
| Economic Instrument | E | Direct investment | D | Funds to sub-national governments | F |
| | | | | Infrastructure investments | I |
| | | | | Procurement rules | P |
| | | | | RD&D Funding | R |
| | | Fiscal/Financial incentives | F | Feed-in tariffs/premiums | F |
| | | | | Grants and subsidies | G |
| | | | | Loans | L |
| | | | | Tax relief | Tr |
| | | | | Taxes | T |
| | | | | User charges | C |
| | | Market-based instruments | M | GHG emissions allowances | A |
| | | | | Green certificates | G |
| | | | | White certificates | W |
| Information & education | I | Implementation advice/Aid | A | | |
| | | Information provision | I | | |
| | | Performance label | L | Comparison label | C |
| | | | | Endorsement label | E |
| | | Professional training & qualification | T | | |

| Main Type | | Sub Type 1 | | Sub type 2 | |
|---|---|---|---|---|---|
| Policy support | P | Institution creation | I | | |
| | | Strategic planning | S | | |
| | | Auditing | A | | |
| Regulatory instruments | R | Codes & standards | C | Building codes & standards | B |
| | | | | Product standards | P |
| | | | | Sectoral standards | S |
| | | | | Vehicle fuel economy & emissions standards | V |
| | | Monitoring | M | | |
| | | Obligation schemes | Ob | | |
| | | Other mandatory requirements | O | | |
| Research, development & deployment (RD&D) | RD | Demonstration project | D | | |
| | | Research program | R | Technology deployment and diffusion | Dp |
| | | | | Technology development | Dv |
| Voluntary approaches | V | Negotiated agreements (Public-private sector) | N | | |
| | | Public voluntary schemes | V | | |
| | | Unilateral commitments (Private sector) | C | | |

IEA 4E EDNA Annex: "Encouraging Intelligent Efficiency - Study of policy opportunities", 2017

## PECTA – available results

- **WBG-technology challenges ( = hurdles)**
  - Temperature increase
  - Gate voltage limits (particular GaN)
  - *Reliability*
  - High switching frequency
  - New packages and topology solutions
  - *Cost*
  - Shortage of materials (particular SiC)
  - Wafer diameter
  - Standardization (Comparability)



## PECTAs' goal and ongoing activities (2020 – 2024)

**PECTA goals:**

Collecting and analyzing information about new wide band gap (WBG) based power electronic devices;

Coordinating of international approaches that promote WBG-based power electronics

Developing greater understanding and action amongst governments and policy makers.

**Tasks:**

*Task A:* Completing and updating available efficiency figures

*Task B:* Energy and environmental related life cycle assessment (LCA)

*Task C:* Revision of elaborated application readiness maps (ARMs)

*Task D:* Policy measures and mapping with applications on a timeline

*Task E:* Standards to support the WBG-market entrance

*Task F:* Measurement of power supply efficiency

# Swiss Activities in the WBG-Power Electronic Area (selected)

Power Electronic Conversion Technology Annex PECTA

***GaN-based Power Electronics for Energy Efficiency Applications***

*EPFL,* Completion Q1 2019 (https://www.aramis.admin.ch/Texte/?ProjectID=36837)

Investigating the increase of system efficiency in power conversion by using GaN semiconductor technology

***High-efficiency power converters for potentially-large energy-savings applications***

*EPFL*, Completion Q2 2020 (https://www.aramis.admin.ch/Texte/?ProjectID=40293)

Design and demonstration of power converter circuits with large energy saving potential for demanding applications such as PV microinverters and LED-based street lighting

***Advanced SiC Material for Power Electronic Devices (Ampere)***

*FHNW / HITACHI-ENERGY,* Completion Q3 2021 (https://www.aramis.admin.ch/Texte/?ProjectID=40193)

Development of advanced high voltage SiC device technologies that go beyond the state of the art. The focus was on 6.5 and 10 kV SiC switches and diodes.

***Roadrunner Commercial Vehicle Inverter and Testing on eBus Line***

*ABB / RVBW / FHNW,* Completion 2022 / 2023 (extension)

As part of the P+D project "Roadrunner", a fleet of eBuses was to be equipped with a new power converter based on Silicon Carbide (SiC) semiconductors;

# Swiss Activities in the WBG-Power Electronic Area (selected)



## *Swiss Hybrid Inverter*

*FHNW,* Completion Q3 2022

Simulation, construction and measurement of a prototype Si IGBT/SiC MOSFET cross-hybrid-switch with 1,2 kV and 100 kW

## *IEA PECTA: Analysis and Loss Measurements of WBG-based Devices*

*EPFL,* Completion Q2 2024

Development of basics for WBG devices as a basis for future reproducible measurements (prerequisite for standardization)

## *Optimized SiC PV-Converter*

*ZHAW / AIT,* Completion Q4 2023 / Q1 2024

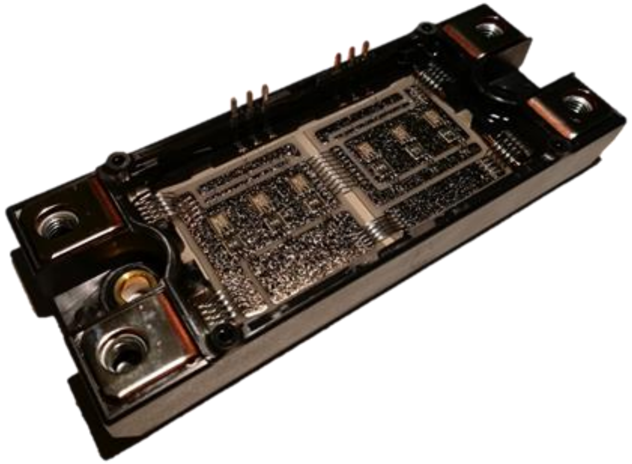
Construction of a PV inverter in the power range of 5-10kW based on a SiC MOSFET bridge from Infineon and comparison with a commercial Si-based PV inverter

## *Optimal, application-relevant and system efficiency of SiC-pump-drive*

*FHNW, Grundfos Pumpen AG*, Completion Q 2025

Development of efficient SiC converter in the range of several kW for water pumps (or water circulated pump)

## Contacts



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