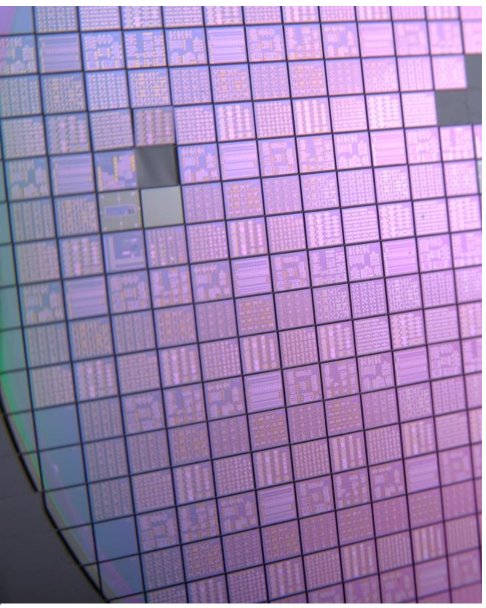
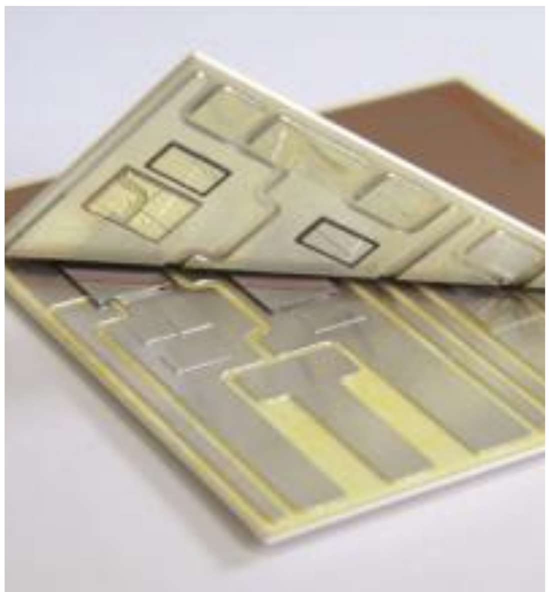
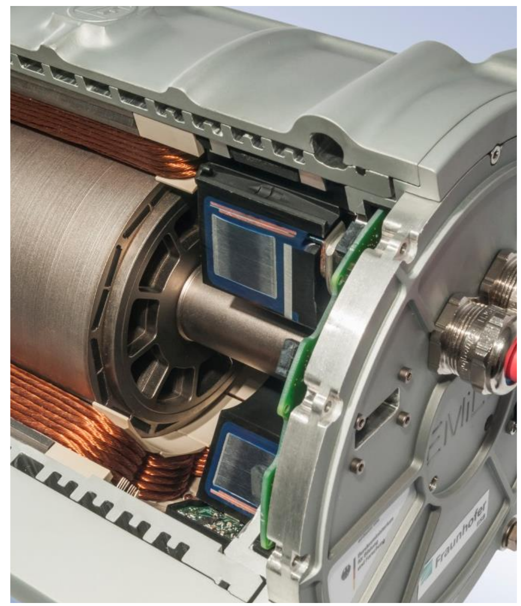
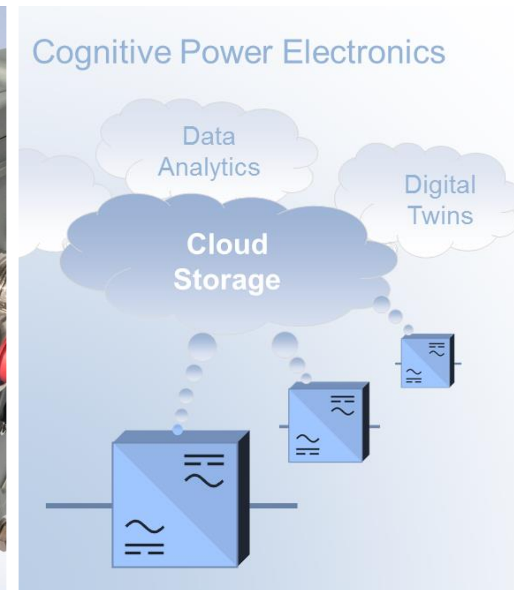
Trends and Challenges in Power Electronics

Prof. Dr.-Ing. Martin März









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Content

- Power electronics in a digital world
- Technological challenges in power electronics

Power Electronics Today

Electrical Energy

AC ~
DC =

Power Electronics

AC ~
DC =

Electrical Energy

Electrical Energy Processing

1101001011011000101
0011100010010111001
1110100100010001010

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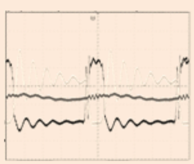
Data & Information

analog
digital

IT Electronics

analog
digital

Data & Information



Data Processing

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Power Electronics Today

IT Electronics

Universal Data Processing Platform

Specific task is simply defined by Apps

today

past

Application specific devices

Power Electronics

Universal Power Processing Platform

?

tomorrow

today

Application specific devices

Software-defined Power Conversion

Siemens »TAPAS Community Challenge«

“TAPAS features a 48V, 3-phase GaN power stage (300 W) with on-board filters. It allows for a high switching frequency/bandwidth (300 kHz and beyond)“

Creative teams worldwide used this „**Software Defined Inverter**“ (SDI) for

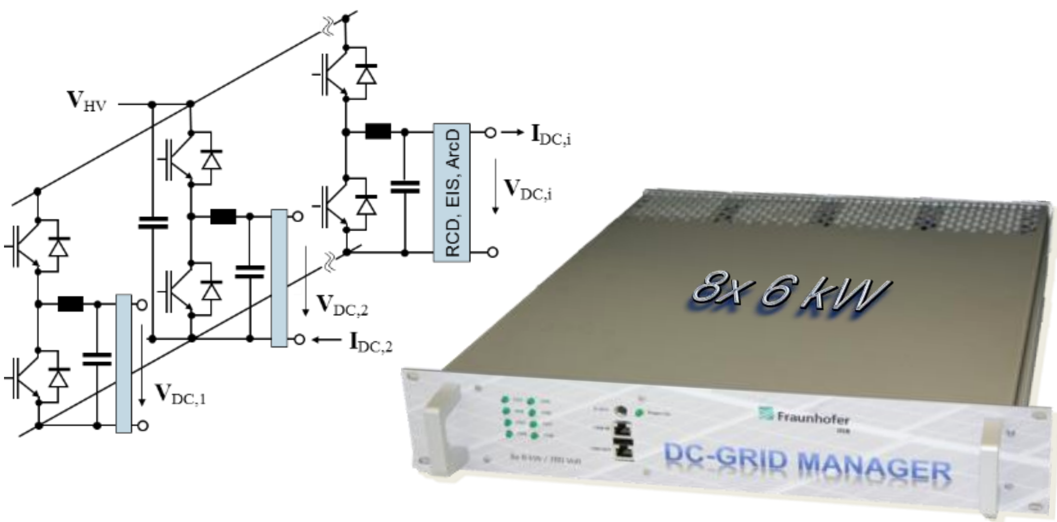
- Class-D audio power amplifiers
- Wireless power transfer (inductive charging)
- Magnetic levitation and 3D positioning
- Faraday modulator (high speed laser power control)
- ….,
- and, of course, also for various electric drive applications

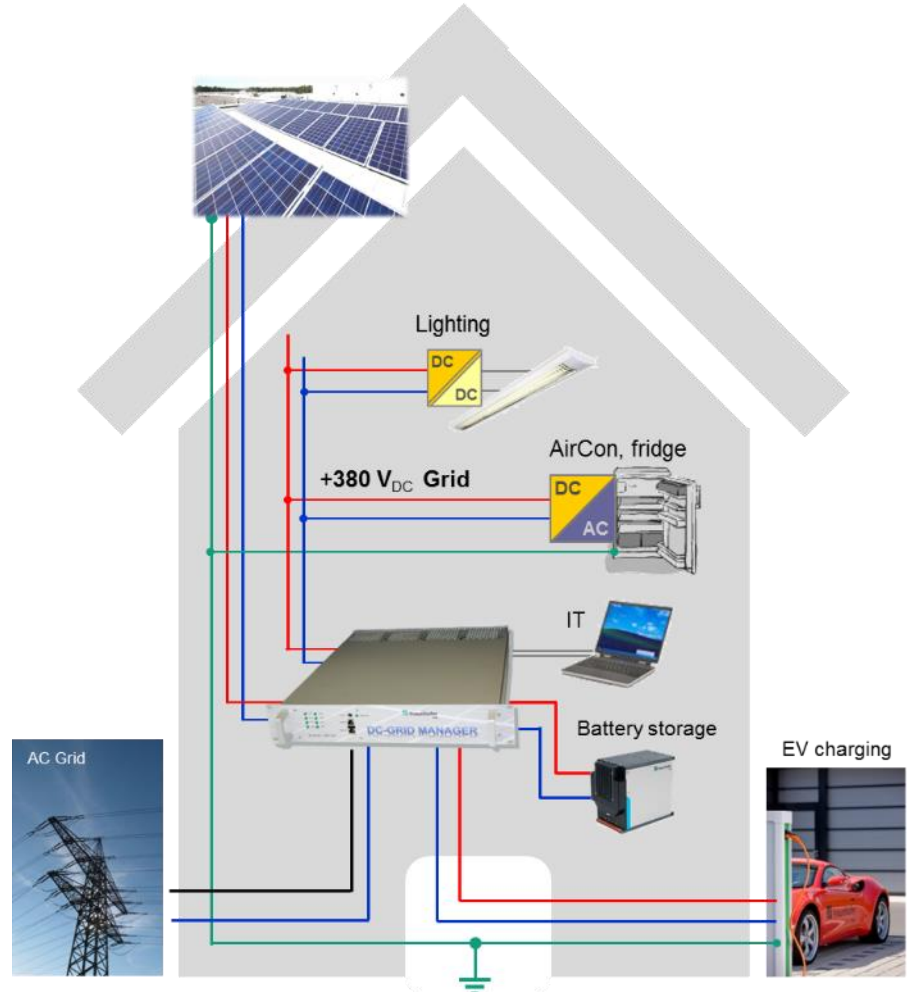
Software-defined Power Conversion

DC-Grid Manager (Fraunhofer-IISB)

Several identical DC channels that can be arbitrarily configured via software (IP/LAN)

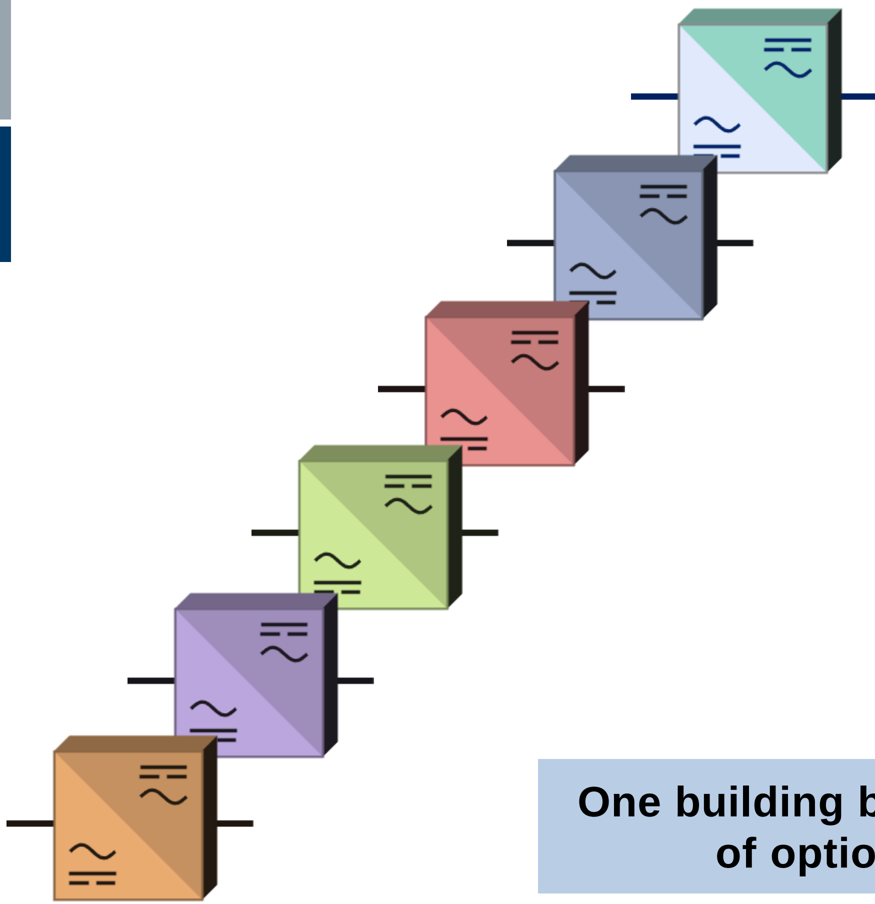
- voltage or current controlled source or sink
- complex control functions like MPP tracking, battery management or droop control
- individual fault characteristics (short circuit, overload, etc.)





Power Electronics Tomorrow

Software-defined Power Conversion



Reduction of

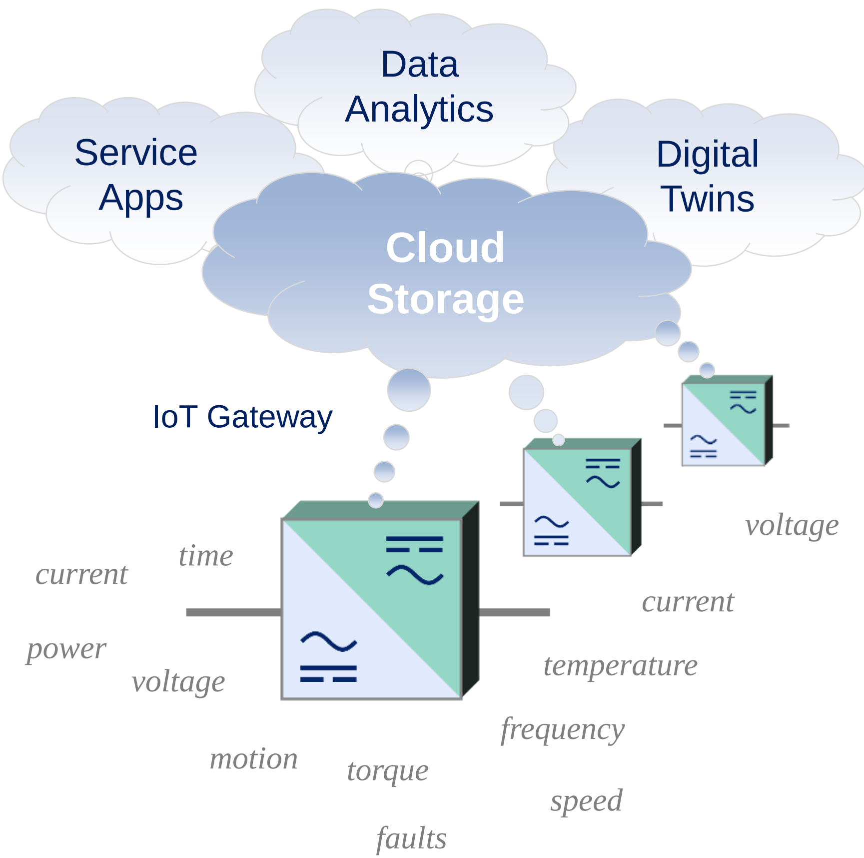
- cost by high volume production
- warehousing costs
- installation work
- service cost and down time.

Increase in

- flexibility regarding requirement changes

One building block and an infinite number of options for customization

Power-as-a-Sensor



Power-as-a-Sensor

A variety of physical parameters is continuously measured in each power converter. The idea:

- make these data externally available in a secure way, and
- provide power supply and gateway functionality for application specific sensors

… and even for advanced sensors, cost become more and more negligible (s. Smartphones)

Power-as-a-Sensor

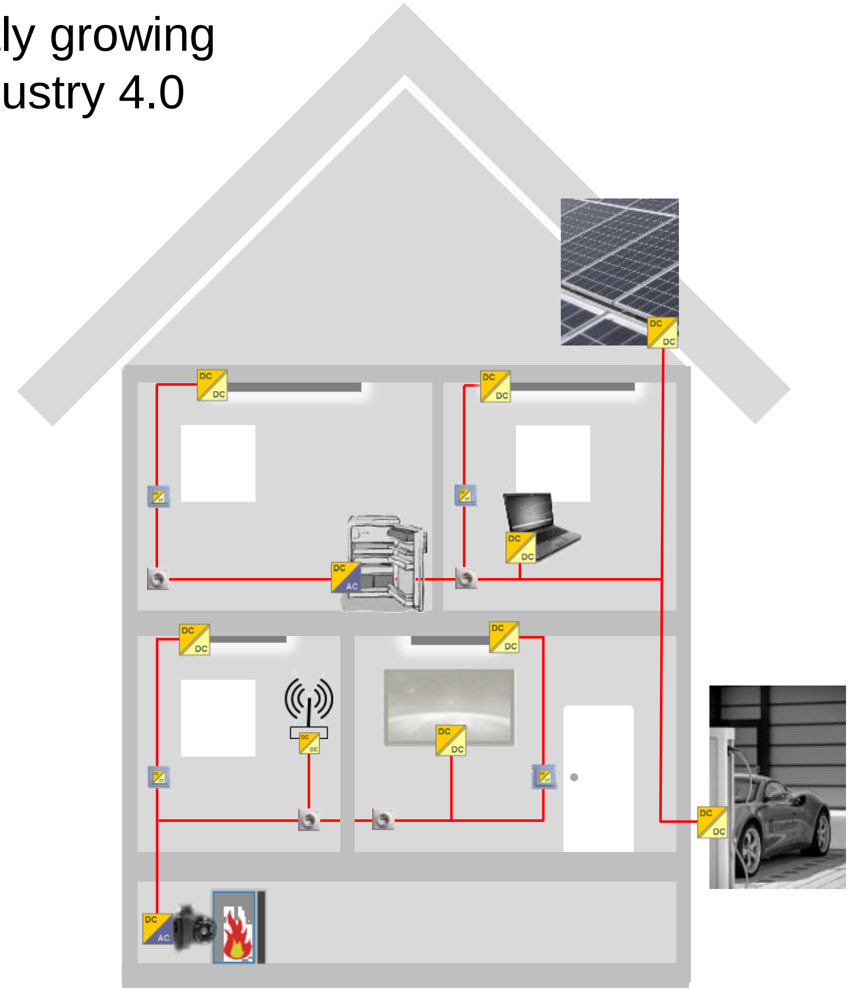
Sensors are ubiquitous and their number is constantly growing not only because of Internet-of-Things (IoT) and Industry 4.0

Get rid of

- back-up batteries
- energy harvesting
- extra cable installations
- extra stand-by losses

by using the omnipresent power converters as sensor platforms - because:

»**Energy is where Power Electronics is!**«



Power-as-a-Monitor

Edge Computing

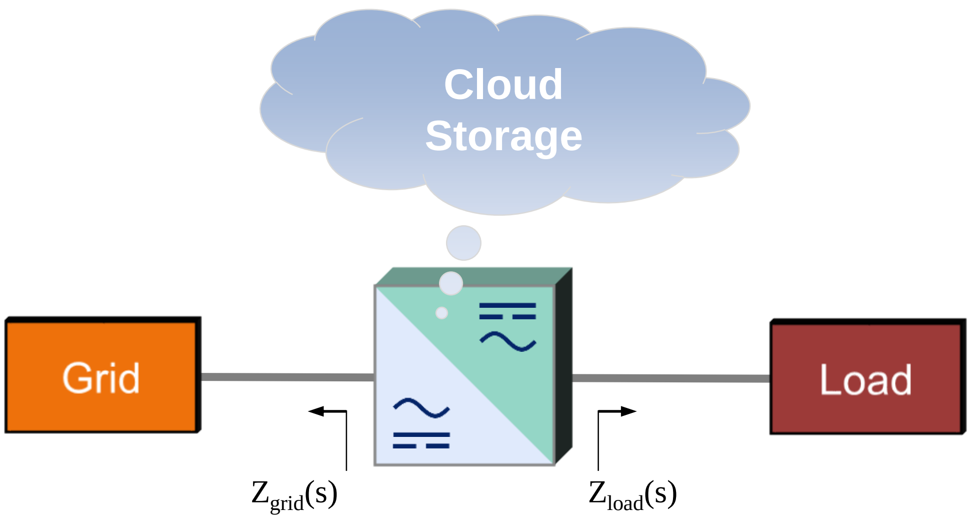
Derive aggregated higher-level information, using the data measured within a power electronic, for monitoring the grid, load and/or system environment:

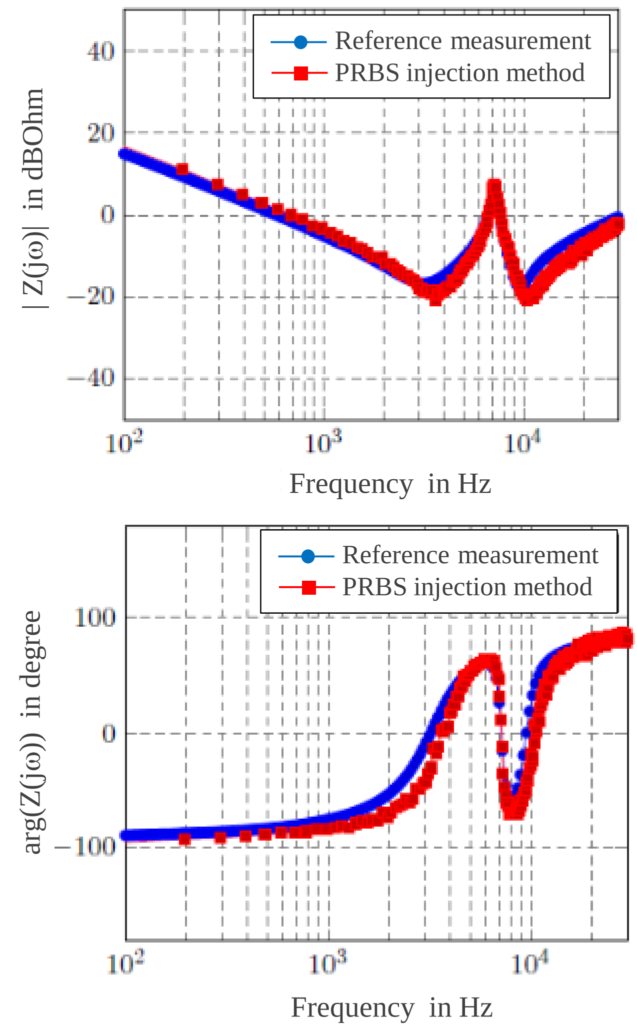
- operating times, utilization rates
- production process variations
- predictive maintenance
- fault situations
- …

Power converters: The perfect system monitors!

Power-as-a-Monitor

Low-cost Impedance Monitoring



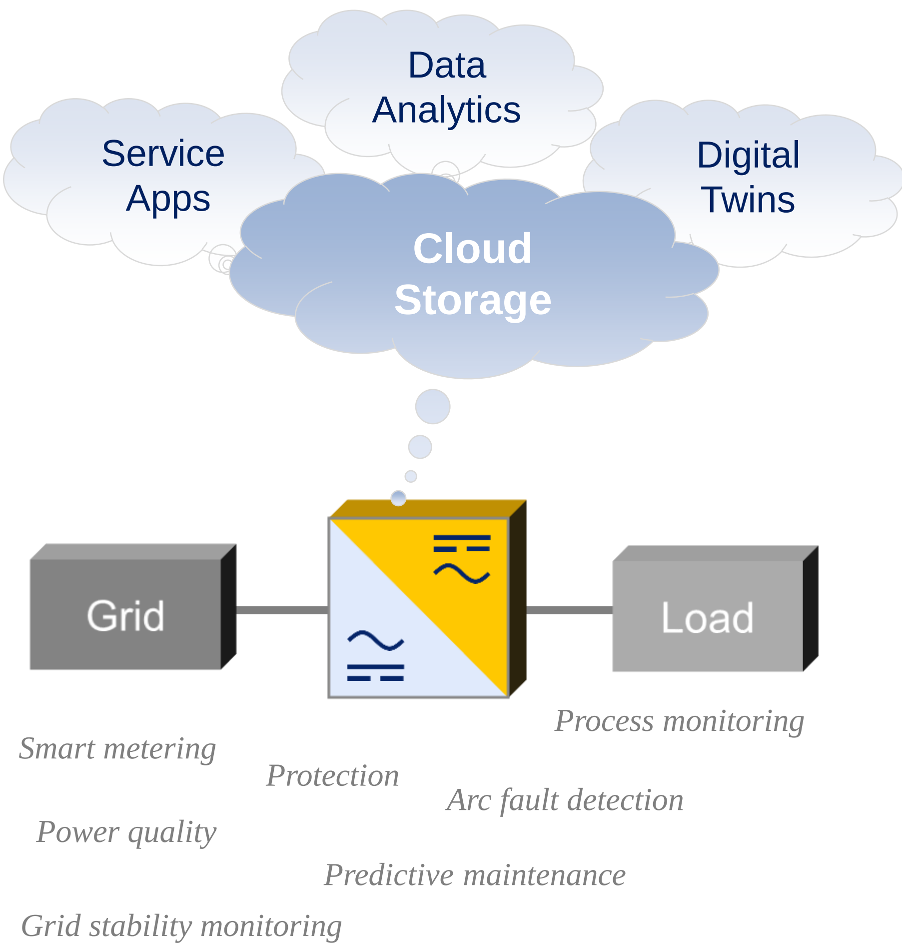


Bildquelle: Masterarbeit Fabian Bodensteiner

- Grid a/o load monitoring
- Detection of faults, arc or instabilities
- Active damping, self-adapting control
- Process monitoring, predictive maintenance

Power Electronics Tomorrow

Power-as-a-Monitor



Aggregated Information	to be used for e.g.
Active, reactive power	• smart metering
Total harmonic distortion	• grid a/o load monitoring
Abnormalities in the (EMI) noise spectrum	• arc fault detection • service request • predictive maintenance
Impedance characteristics	• grid a/o load monitoring • self-adjusting controllers • fault detection
Coulomb counting	• battery management
Mission profile	• life estimation

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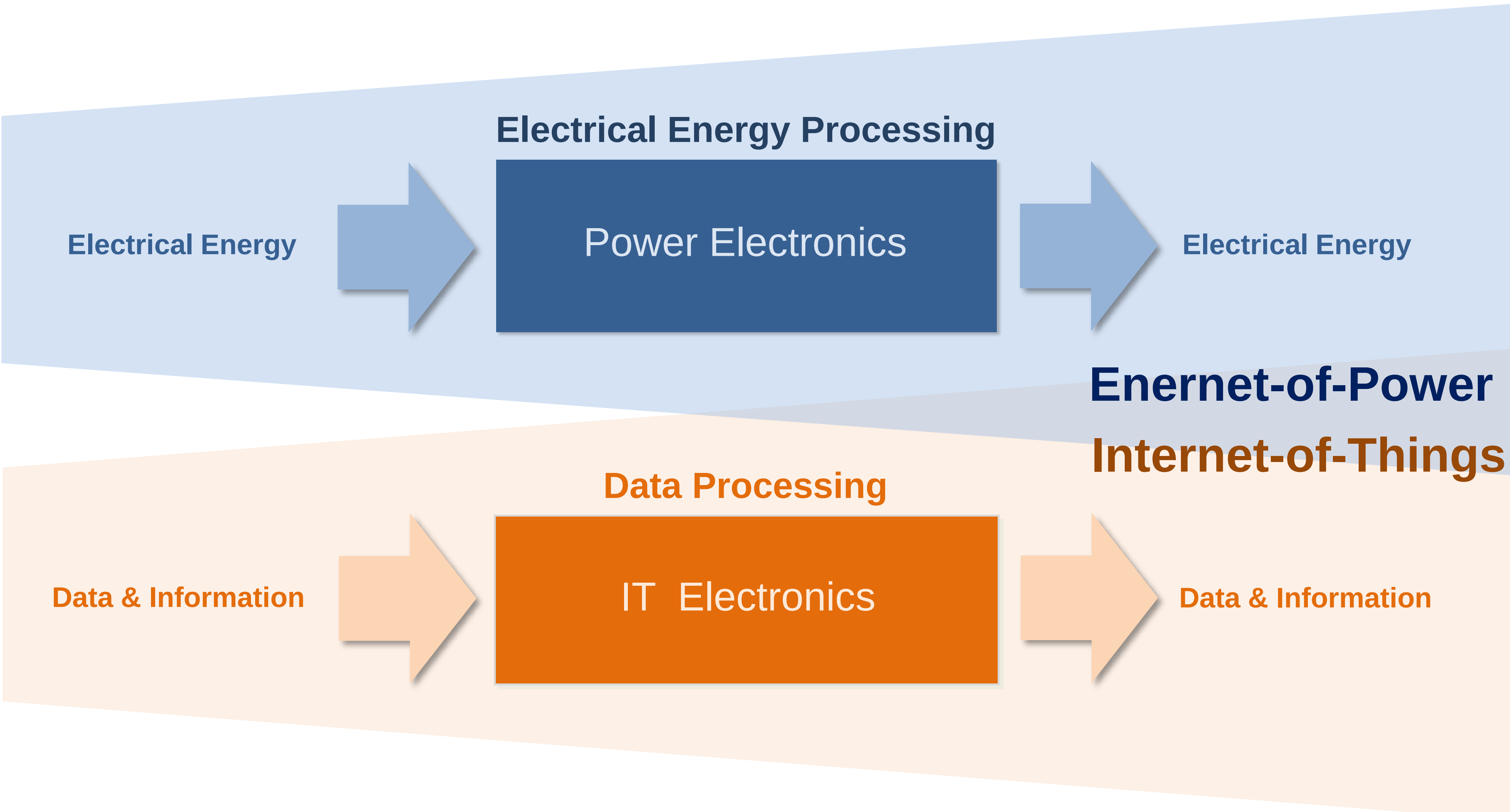


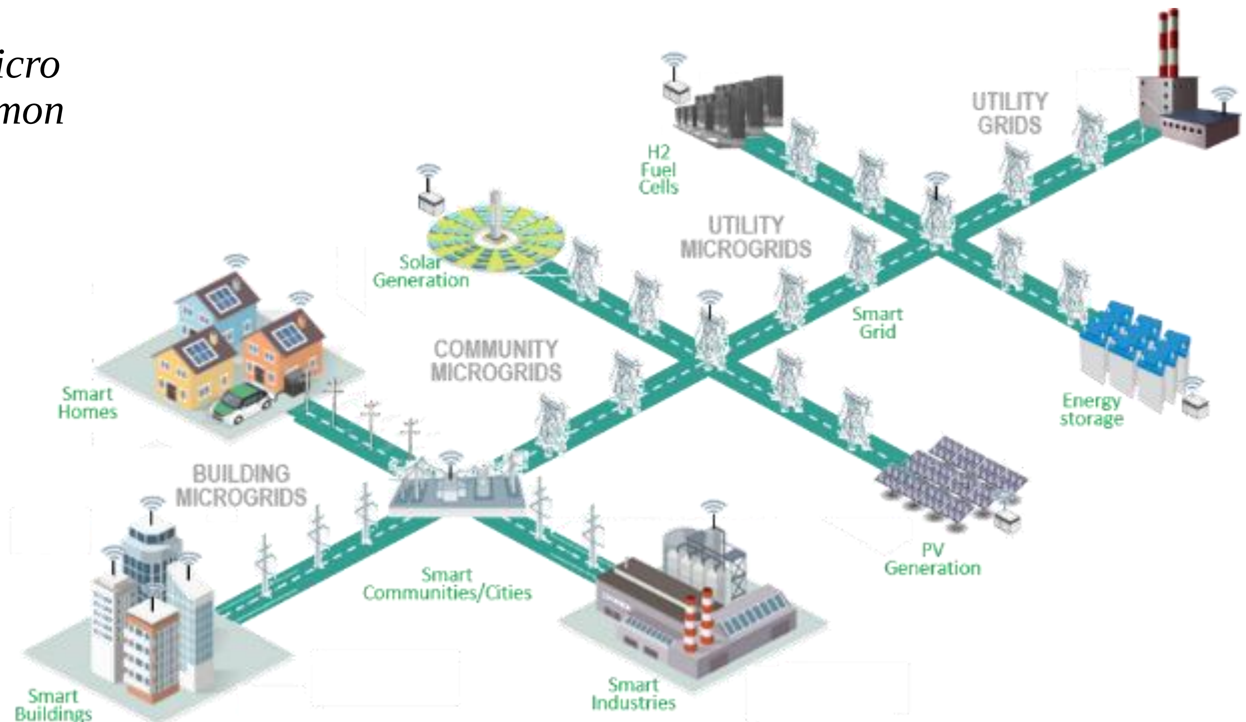
Enernet-of-Power

doing for electricity what the Internet did for information

"A vast electrical power network linking smaller grids in successive layers worldwide. The ***Enernet*** *includes commercial, educational, governmental, and other micro and macro grids, all of which use a common set of electrical and communications standards."*

Brian Patterson - President, Emerge Alliance

(IEEE ICDCM Conference, Nuremberg, 2017)

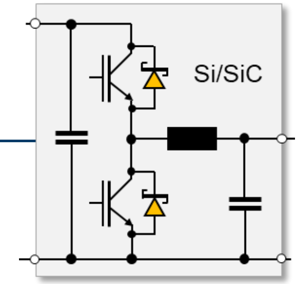


Picture: www.emergealliance.org

Content

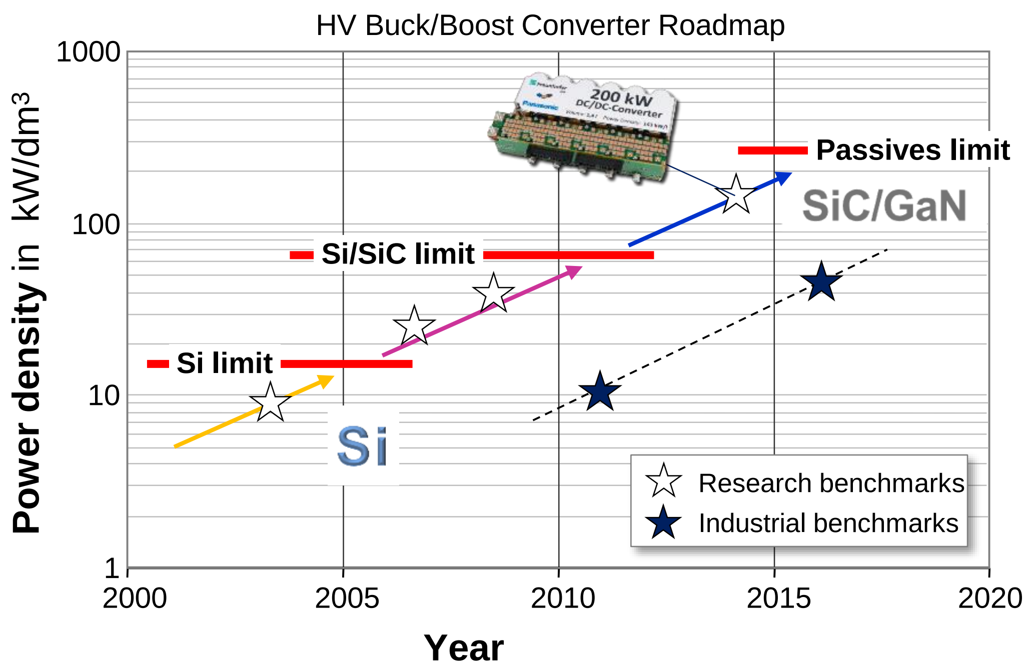
- Power electronics in a digital world
- **Technological challenges in power electronics**

Power Electronics Tomorrow



»Moore's Law« in Power Electronics

Continuous Progress in Power Density



Limitations today are **not** power semiconductors!

Progress is needed in

- passive devices
- integration of logic and power
- packaging technologies
- manufacturing and assembly technologies
- thermal management
- EMI management

Power Electronics Tomorrow

New technological challenges arise from extreme application requirements

- Continuous operation for 20 to 40 years
- Maximum availability (fail operational)
- High ambient temperatures
- High operating altitudes
- Reduced air pressure
- Cosmic ray

Picture: Fraunhofer-IISB

Picture: Siemens

Picture: Airbus

Picture: NASA

Power Electronics Tomorrow

A much higher degree of integration is necessary!

- **Chip Level Integration** (monolithic or multi-chip)
  - power + driver + logic
  - indispensable with GaN
  - up to multi-kW

- **3D Heterointegration**
  - additive manufacturing technologies (metal, ceramic, polymers) for functional integration of active and passive devices, interconnects, housing and cooling functionalities
  - laser-based fine structuring
  - new joining processes
  - new insulation and coating systems
  - up to multi-MW

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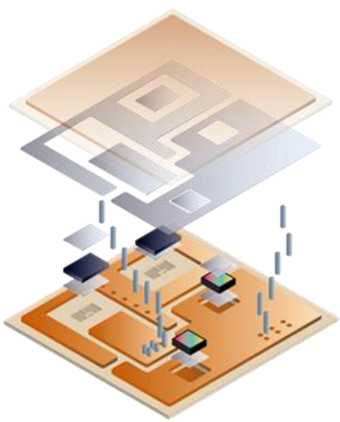
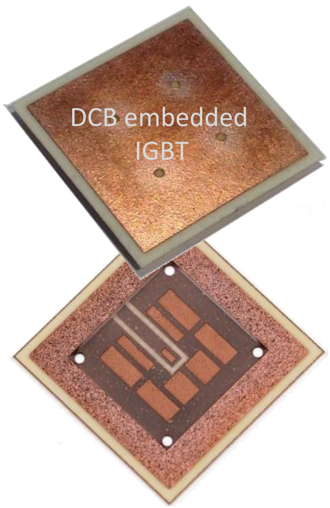
Challenges for Packaging Technologies

- Harness the high possible chip temperatures of WBG power semiconductors
- Improve reliability and thermal management
- Increase transient overload capability
- Cut costs
- Minimize circuit parasitics

⇨ **Organic substrates will not meet harsh application requirements** (automotive, aviation)

Power semiconductors embedded in DCB substrates





Pictures: Fraunhofer-IISB

Key Technologies

- Laser (fs) structuring of DCB substrates
- Sinter bonding

Advantages

- Hermetic sealed
- No organic materials
- Chip operating temperature > 250(300)°C
- Negligible circuit parasites
- True double-sided cooling

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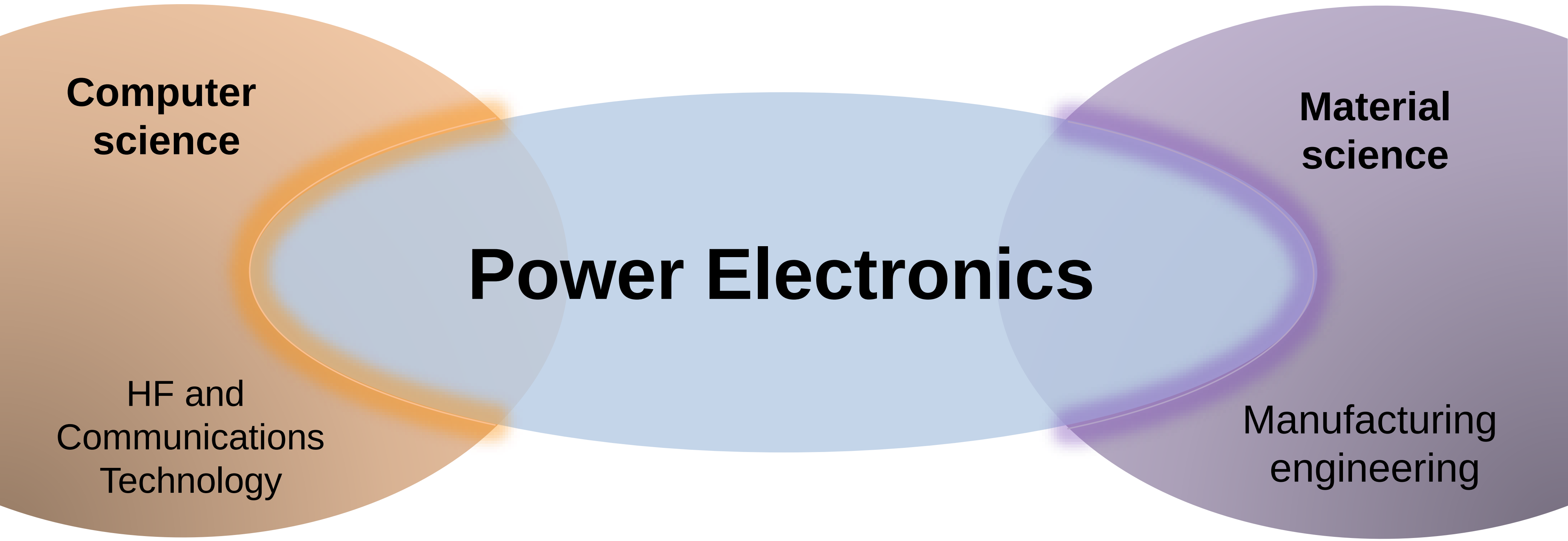
Innovations will increasingly arise at the interfaces to other disciplines



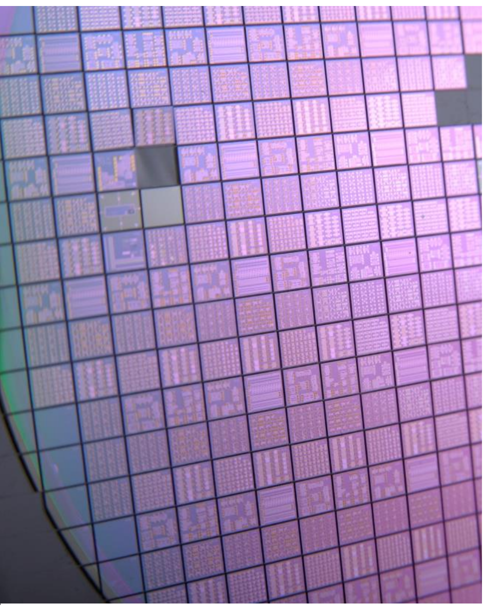
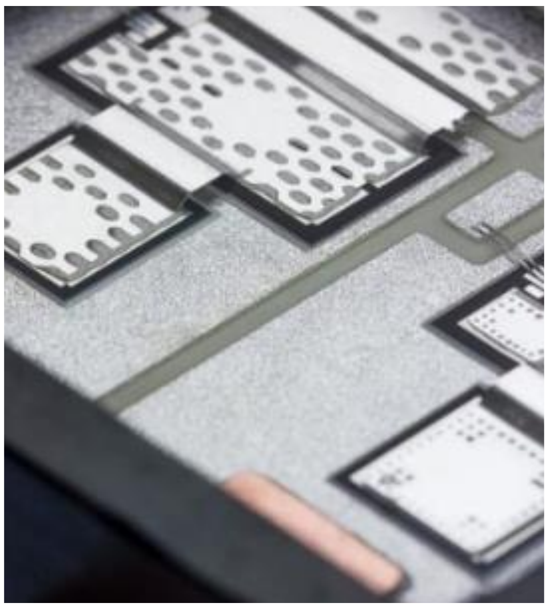
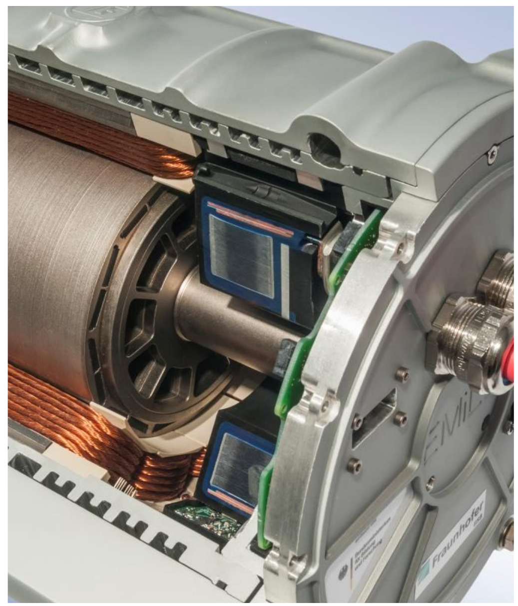
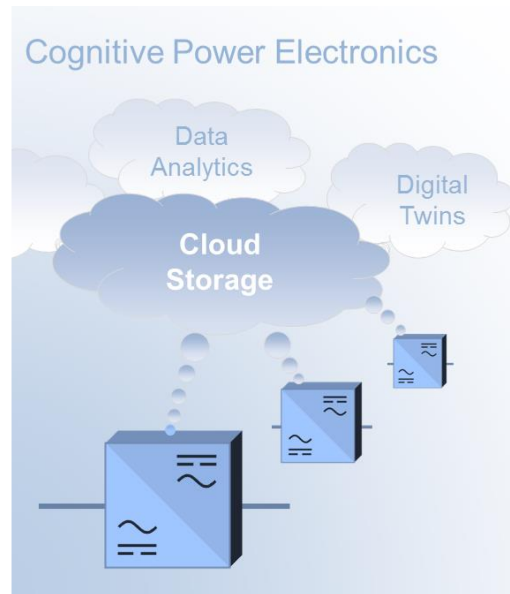
Power Electronics Tomorrow

Power Electronics

Key technology for a modern all-electric and all-digital society

Thank you for your Attention

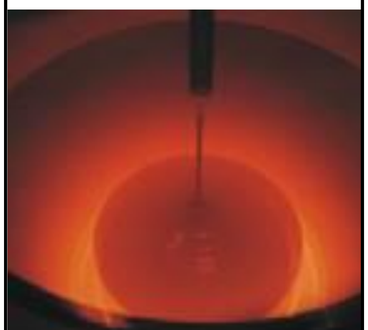
looking forward to an inspiring discussion

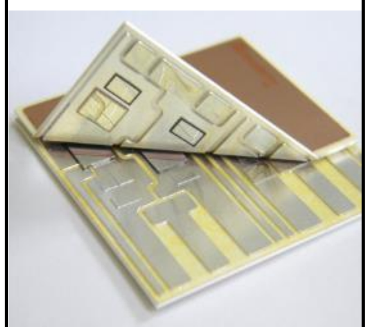





Power Electronics at Fraunhofer-IISB

Power Electronics

Business Area **Semiconductor Technologies**			Business Area **Power Electronic Systems**	
Materials	Technology	Devices Packaging Reliability	Vehicle Electronics	Intelligent Energy Systems





Application Center for Decentralized Energy Systems