Inverter Market Trends 2013 - 2020 and Major Technology Changes

February 2013

A big dive into the heart of the power electronics industry, from systems to active & passive components

REPORT SAMPLE






YOLE Développement

Table of Contents

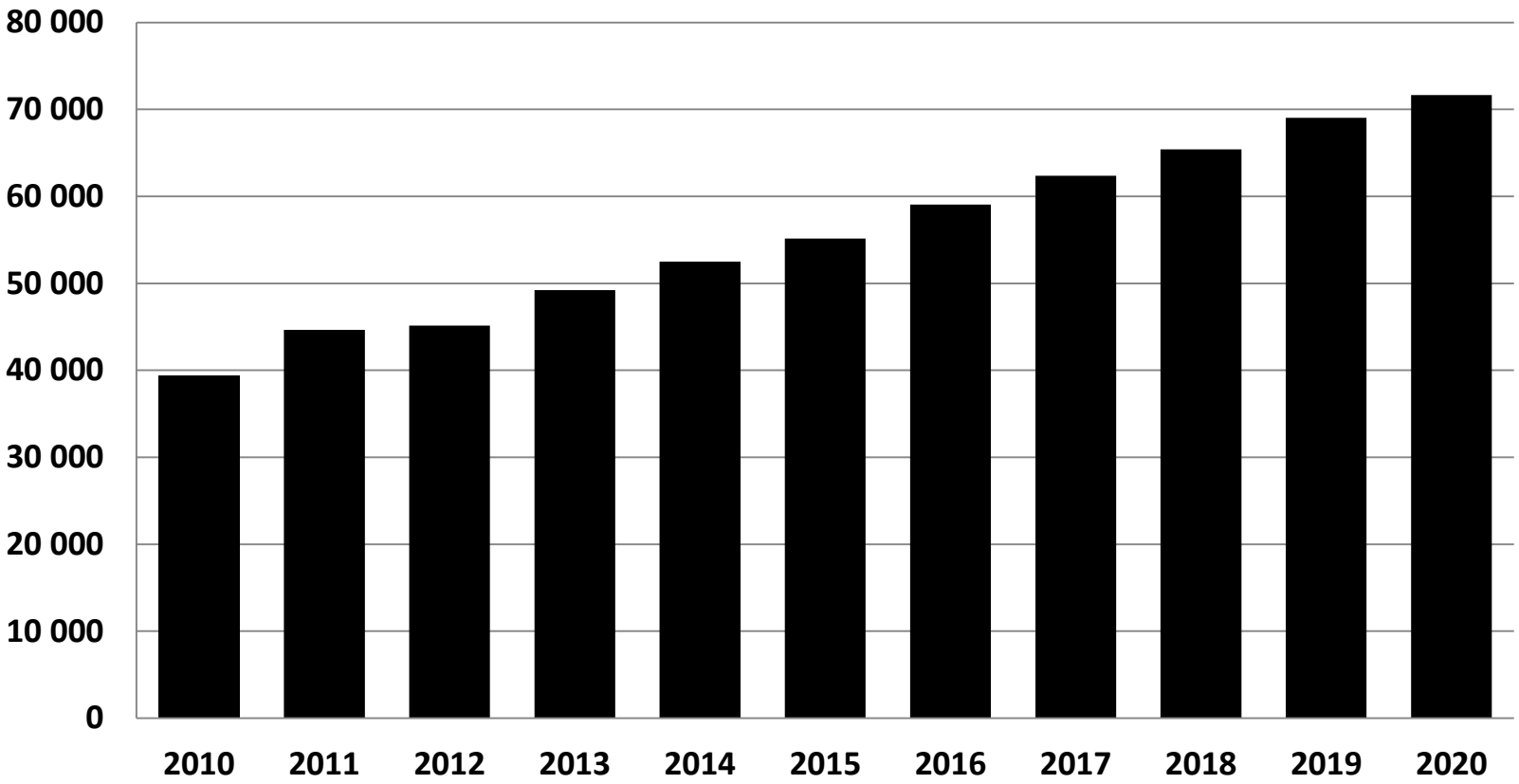
- Glossary p. 3
- How Is the Report Built? p. 4
  - A Two Part Report
  - Methodology, Limitations and Yole's Proprietary Tools
  - Top-Down Approach Report
  - Why Such a Report?
- What Is New in This Report? p. 9
  - What We Saw…
  - … What We Missed
  - What We Can Expect for 2013
- Executive Summary p. 13
- Technological Briefing p. 40
- Compiled Market Forecasts p. 51
  - Inverters
  - Power Modules (split by application and technology)
  - Capacitors
  - Resistors
  - Connectors
  - Busbars
  - Magnetics
- Applications Analysis p. 63
  - PV Inverters p. 65
    - Market metrics (MW, units, revenues)
    - Technological trends for passives and semiconductors
    - Supply chain
  - EV/HEV p. 92
    - Market metrics (units, revenues split by car technology)
    - Technological trends for passives and semiconductors
    - Power packaging
    - Supply chain
  - Wind Turbines p. 129
    - Market metrics (MW, units, revenues)
    - Technological trends for passives and semiconductors
    - Supply chain
  - Rail Traction p. 149
    - Market metrics (units, revenues split by train size)
    - Technological trends for passives and semiconductors
    - Supply chain
  - UPS p. 173
    - Market metrics (units, revenues split by power range)
    - Technological trends for passives and semiconductors
  - Industrial Motor Drives p. 186
    - Market metrics (units revenues, split by power range)
    - Technological trends for passives and semiconductors
- Analytical Comparison p. 197
  - Application Priorities by Market Drivers p. 199
  - Inverter Architecture Trends p. 206
    - Technical trends
    - Price density
    - Power density
  - Power Stacks p. 219
  - Implementation of SiC and GaN Materials in Power Electronics p. 233
  - Passive Components, Packaging and Connectivity Evolution p. 238
  - Supply Chain p. 259
    - Vertical integration
    - Diversification
  - Global Perspectives p. 271
- General Conclusions p. 276

Executive Summary

Inverter market (revenue)

Inverters market (in M$)

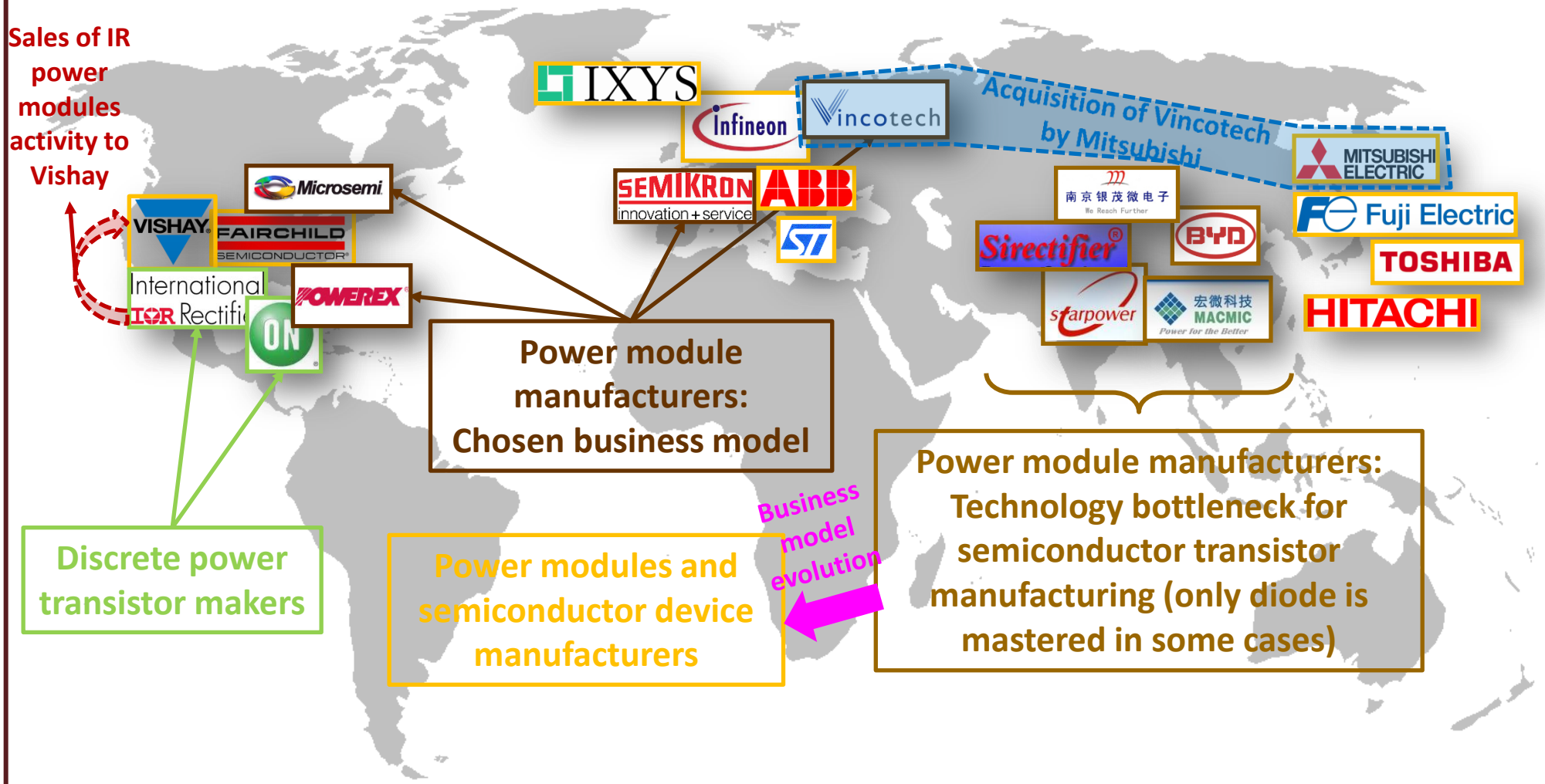
including PV inverter, wind turbine, rail traction, EV/HEV, motor drives & UPS



Analytical Comparison and Global Market Forecasts

Global perspective

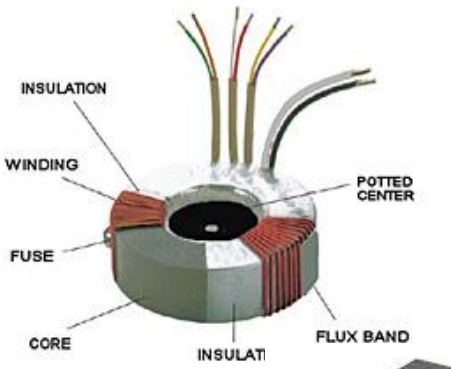
Power module players typology

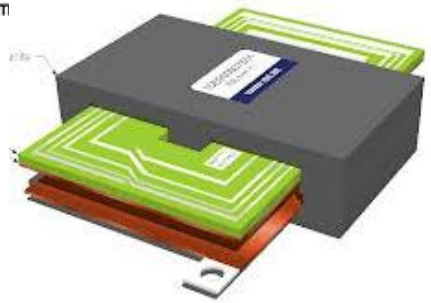


Passive Components

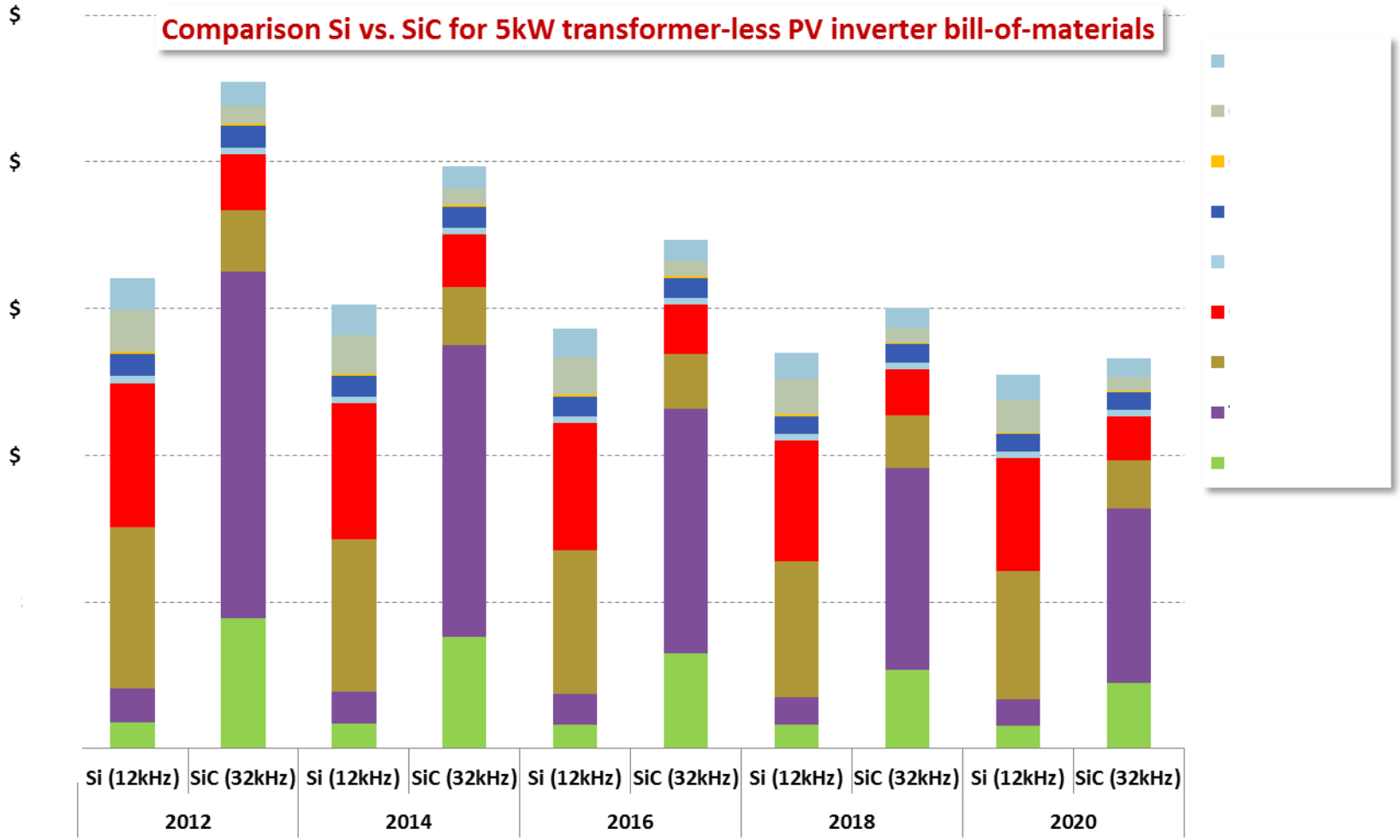
Inductors and transformers

- **To date, there are three main transformer types available:**
  - **Wirewound core or shell type**
    - **The historic type of transformer using a square core, or "E-I" core, and wirewound copper cables**
  - **Toroidal type**
    - **The core is ring shaped, and cables are wound around the core**
  - **Planar type**
    - **This newer type of transformer is proposed only by a few players. The core is similar to a core or shell type transformer. The difference is with the conductor, which is not cable made. A planar conductor is used. For low power, it can be planar lines on a PCB. For high power, the conductor can be made of planar copper rings.**



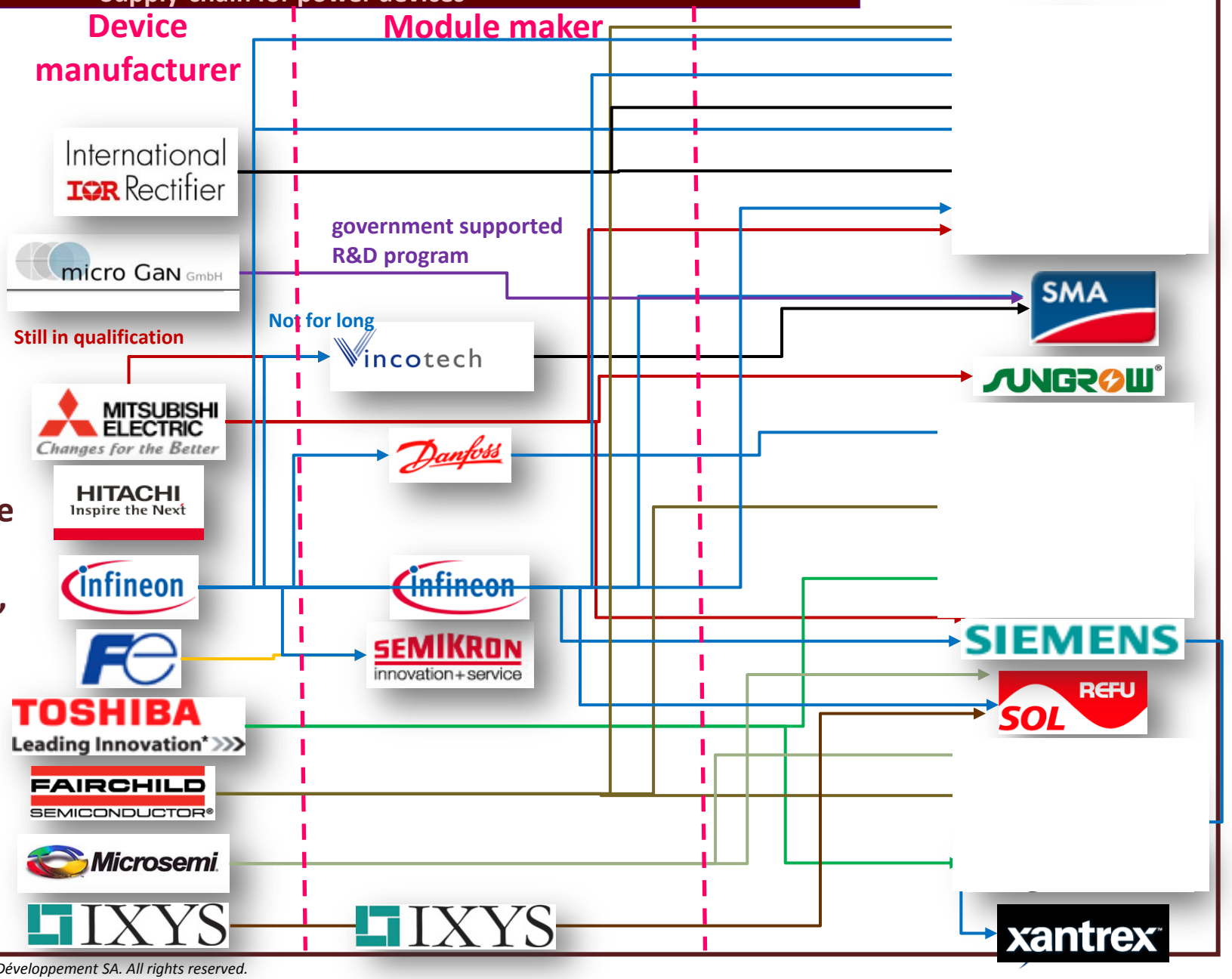


Bill of Materials Comparison Si vs. SiC
Results for 5kW 1-Phase



Power Devices for PV Inverters

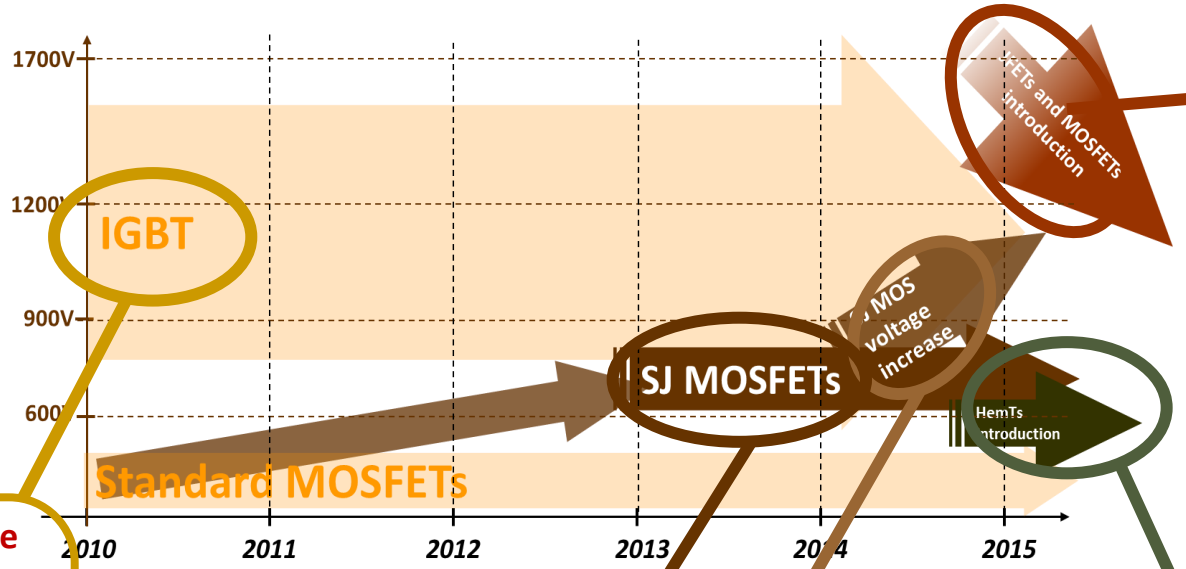
Supply-chain for power devices



- SiC diodes are more and more common, and the only suppliers seem to be CREE, Infineon and Semisouth

Device Roadmap for Full/Plug-In Hybrid and EV

SiC
GaN
Si



IGBTs will stay the preferred device for a long time. With wafer size increasing, it will be even cheaper. We expect it to keep +90% of market share until 2019. Then the market will begin to move to compound semiconductor

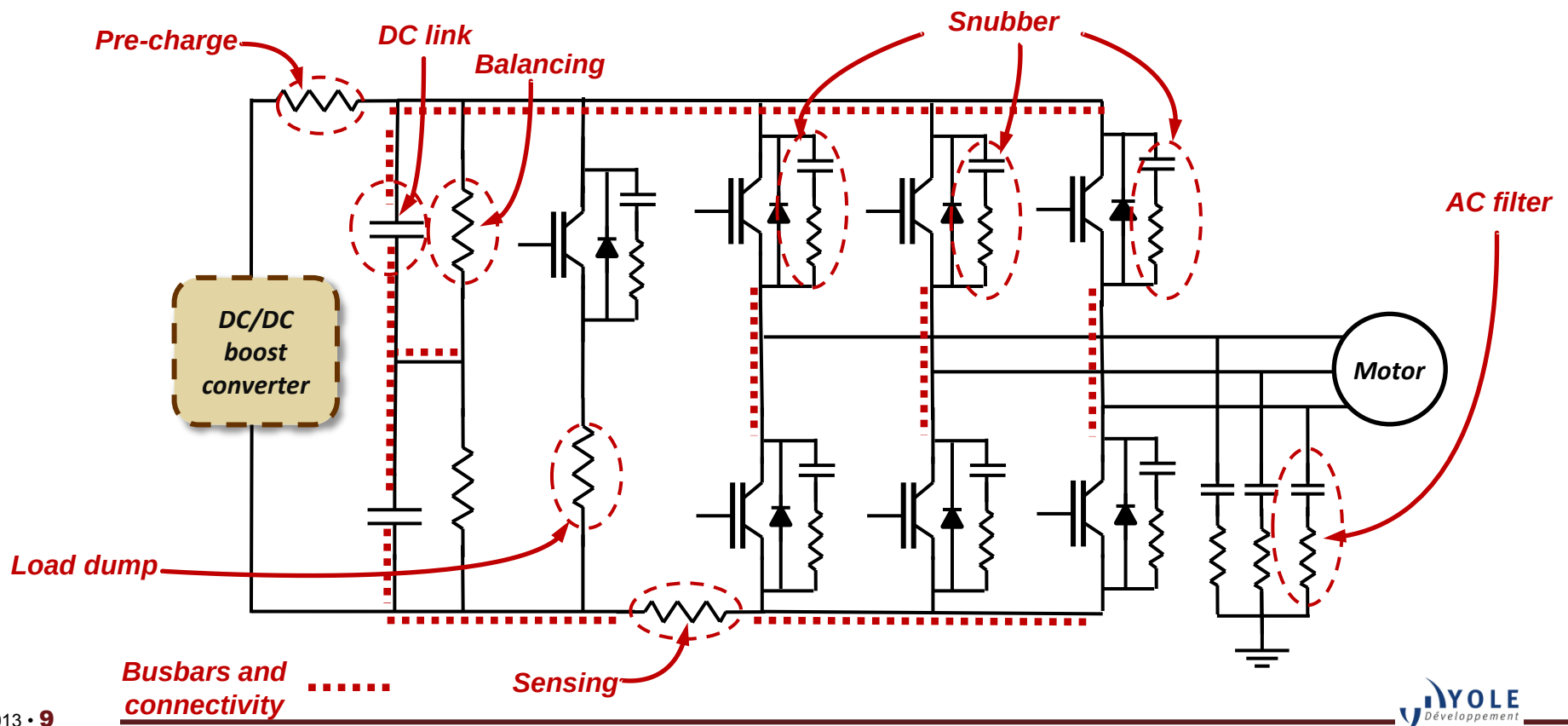
Super Junction MOSFET market penetration will depend on its ability to move to higher voltages. ST Micro has promised to do so. It could be a very good challenger to IGBT for the next 10 years. If we come with 1200V or 1700V SJ MOS that can handle the current, then the technology will explode. If not, it will be constrained to very small urban HEV.

SiC JFET and MOSFETs will start from higher voltages. They will not be available at reasonable prices before 2015. They will stay in high-end products, and mostly on EV. We do not expect these devices to take a big market share (About 3% in 2020)

GaN HemT will have to come with higher voltage. They are already promising that for motor drive applications, but EV/HEV requires a lot of current. We have to wait and see. More input is needed for market penetration analysis in Full/Plug-in HEV and EV.

Passive Components - Introduction

- When using higher power, the choice of passive components is critical and must consider the functions where they are applied. We will take a look at the different ***resistors***, ***capacitors***, ***connectors*** and ***busbars*** surrounding the inverter.



Application Priorities by Market Drivers

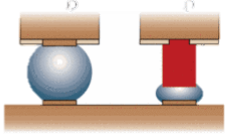
Priority ranking per application

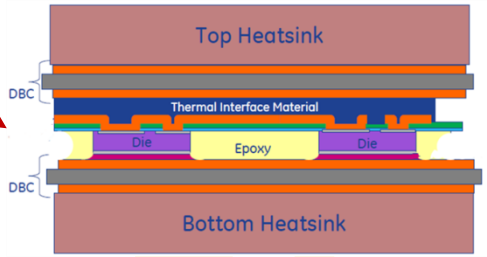
+++: Strong driver
++: Medium driver
+: Low driver

Drivers / Applications	Cost	Performance (efficiency)	Reliability Lifetime	Form factor	Weight
PV inverters	+++	+++	++	+	+
EV/HEV	++	+	+	+++	+++
Wind turbines	++	+++	++	+	+
Rail traction	+	+	++	++	+++
UPS	+++	+	+++	++	++
Industrial motor drives	+++	++	++	+	+

Inverter Architecture Trends: Where Are We Going? With Which Solutions?

- **Thermal management at module level:**
  - Base plate / spreader / passive cooling system ➔ double-sided cooling seems to be the most efficient solution
  - DBC
- **Interconnects and power advanced packaging:**
  - Ribbon bonding
  - Copper bumps and copper pillars

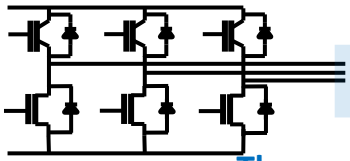


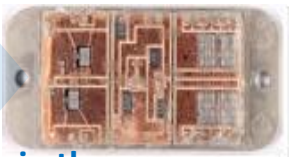


Source: GE Global Research

1MW

100kW

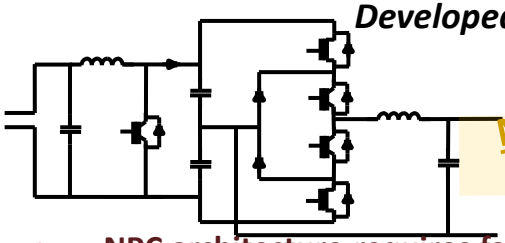




Three phases in the same power module

Developed by device/module makers

10kW



NPC architecture is the most efficient, since it enables reduced voltage and increased component efficiency

Developed by device and module makers

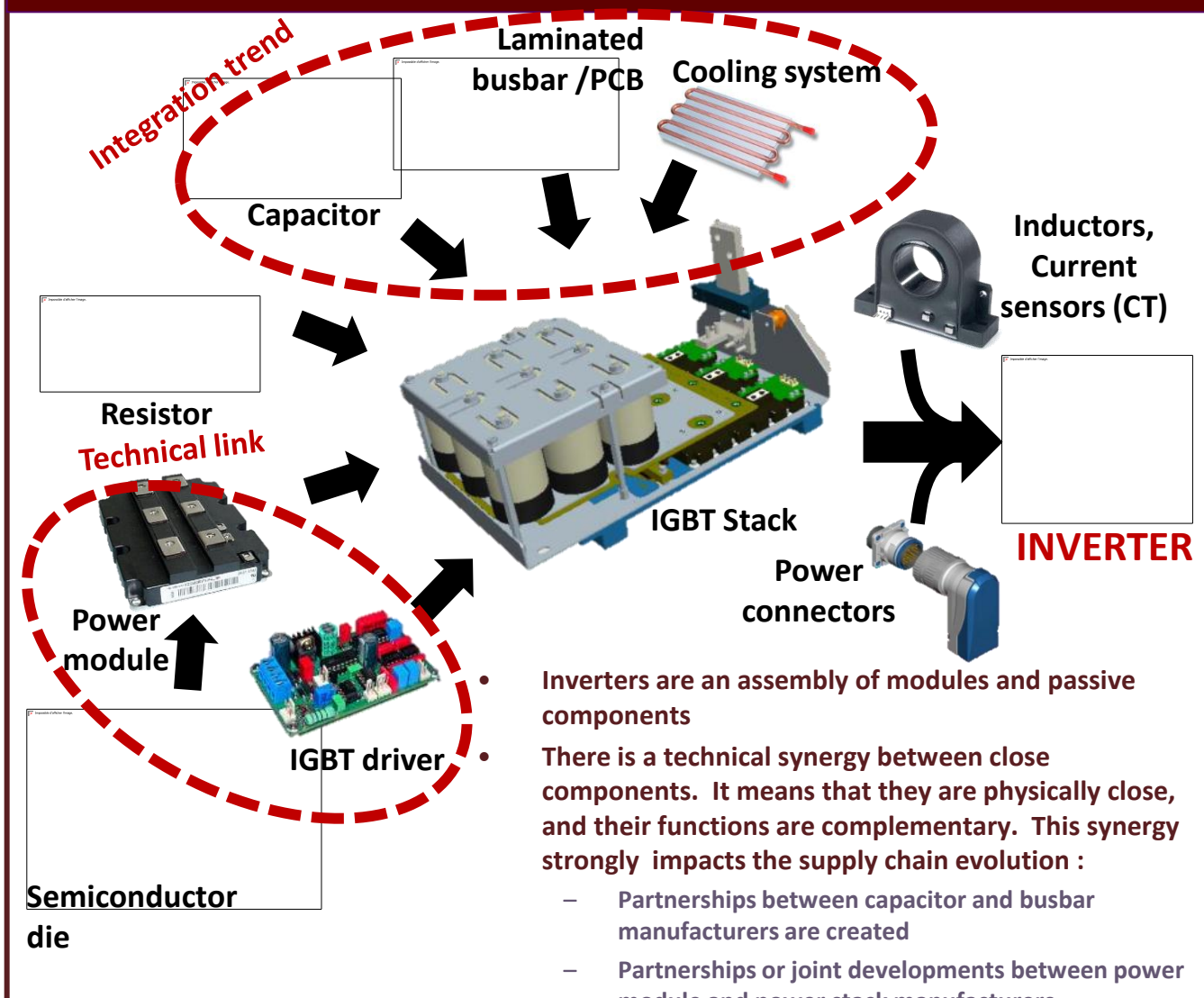
- Then device power range will be increased

1kW

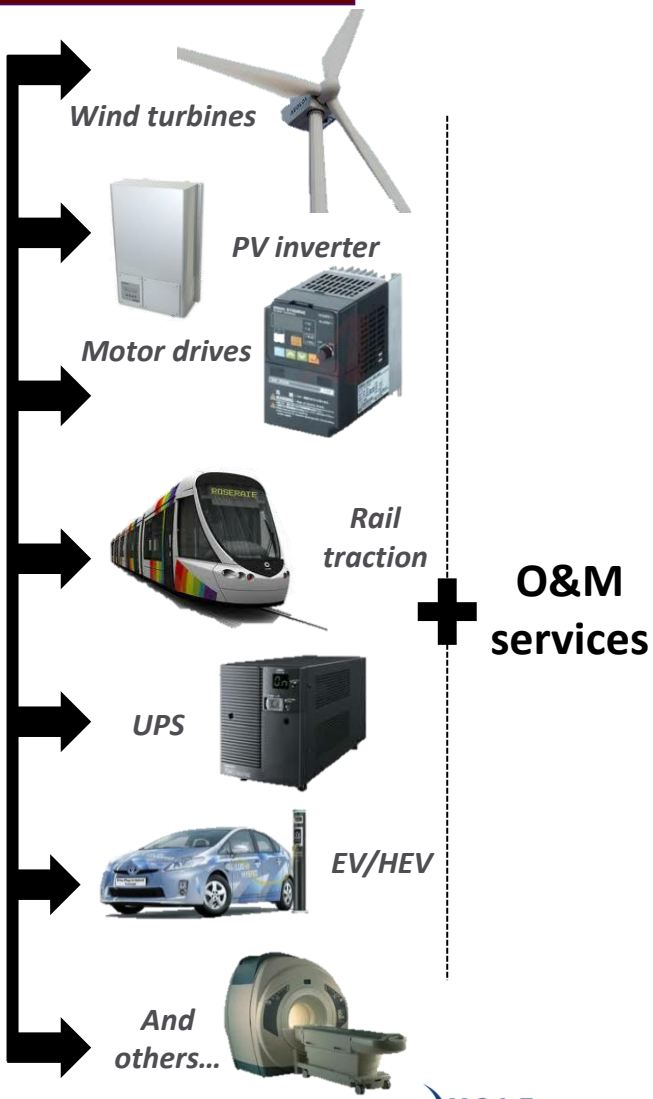
- NPC architecture requires faster switching devices ➔ first step is to decrease cost of high frequency switches such as
  - SiC MOSFETs,
  - GaN HemTs
  - SJ MOSFETs

2011 2012 2013 2014 2015 2016 2017 and later

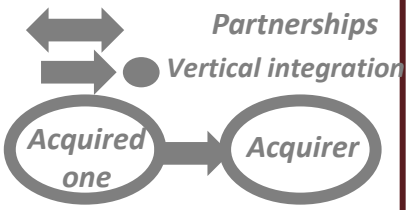
Where Are the Synergies (1/2)



- Inverters are an assembly of modules and passive components
- There is a technical synergy between close components. It means that they are physically close, and their functions are complementary. This synergy strongly impacts the supply chain evolution :
  - Partnerships between capacitor and busbar manufacturers are created
  - Partnerships or joint developments between power module and power stack manufacturers



The Recent Moves: M&As, Partnerships and Developments (1/2)



- **Overview of the current power electronics landscape**

*: Curamik is a power module parts manufacturer (DBCs)

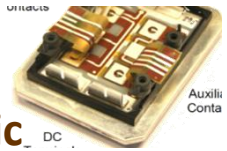
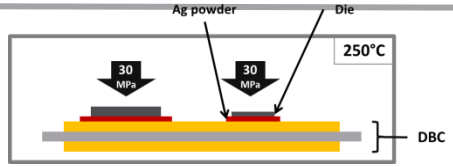
Multiple Components Manufacturers: Summary Table

	Capacitors	Laminated busbars	Inductors	Resistors	Connectors	Other Power electronics parts	Total (2011)
Vishay	$XXM	-	-	$XX M	-	$XX M (semiconductors)	***XX***
Eagtop	$0.1 M	$XX M	$XX M	$XX M	-	$XX M (cooling solutions)	***XX***
SMA group	-	-	$63.0 M	-	-	$XX M (inverters and stacks)	***XX***
CSR	-	$XX M	-	-	-	$XX M (inverters)	***XX***
Rogers	-	$45.0 M	-	-	-	$XX M (DBC)	***XX***
Mersen	-	$XX M	-	-	-	$XX M (cooling systems and protection solutions)	***XX***

- **Several players are involved in manufacturing more than one passive component. This horizontal integration can come from:**
  - **The history of the company, where past events made the company involved in such markets. It comes, most of the time, from opportunistic strategic moves. It is the case for Vishay.**
  - **A planned strategy, which will likely result in the company manufacturing new components. This strategy is then part of the integration trend. This is the case for SMA, Eagtop, Rogers and Mersen.**

Passive Components, Packaging and Connectivity Evolution

Trends in power module packaging

	Current solutions *Widely used by all players*	Emerging technos *At mass production and taking up market shares*	Potential breakthrough *At R&D stage. Still too expensive*
Interconnection	 Al wire bonding	Al ribbon bonding  Copper wire bonding 	Foil sintering Foil ultrasonic wedge bonding 
Die attach	Pb/Sn alloy	 Silver micro powder sintering	Nano powder sintering (no heating and pressure for attach process)
Baseplate Cooling	Baseplate + heatsink AlSiC for long lifetime Al_2O_3 for cost	Thermal exchange improvements:  • Shower power • DBC to heatsink (no baseplate)	 Micro-channel cooling

DBC on both sides:
flip chip
+ Sintering on both sides
+Cooling on both sides

Global Perspective

Power module player typology