

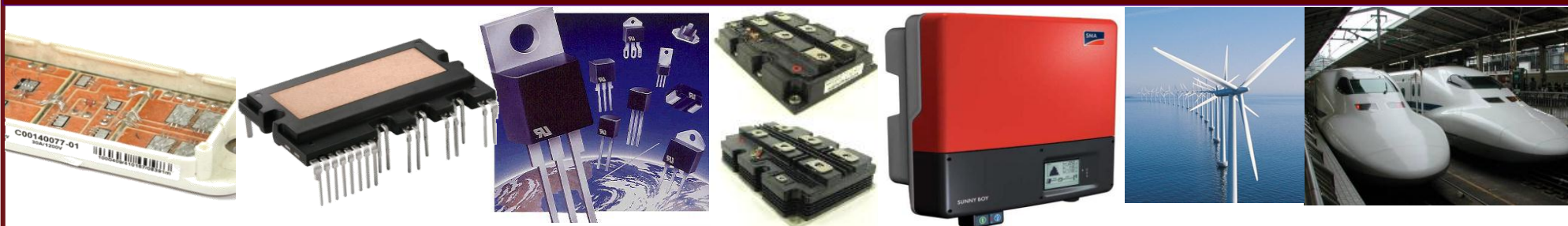
# The IGBT market

## *A new set of rules*

**April 9<sup>th</sup> 2013**

**A Yole Développement Webcast**

*The analysis of this webcast is an extract of the “IGBT market and technologies” report  
To be published in May*



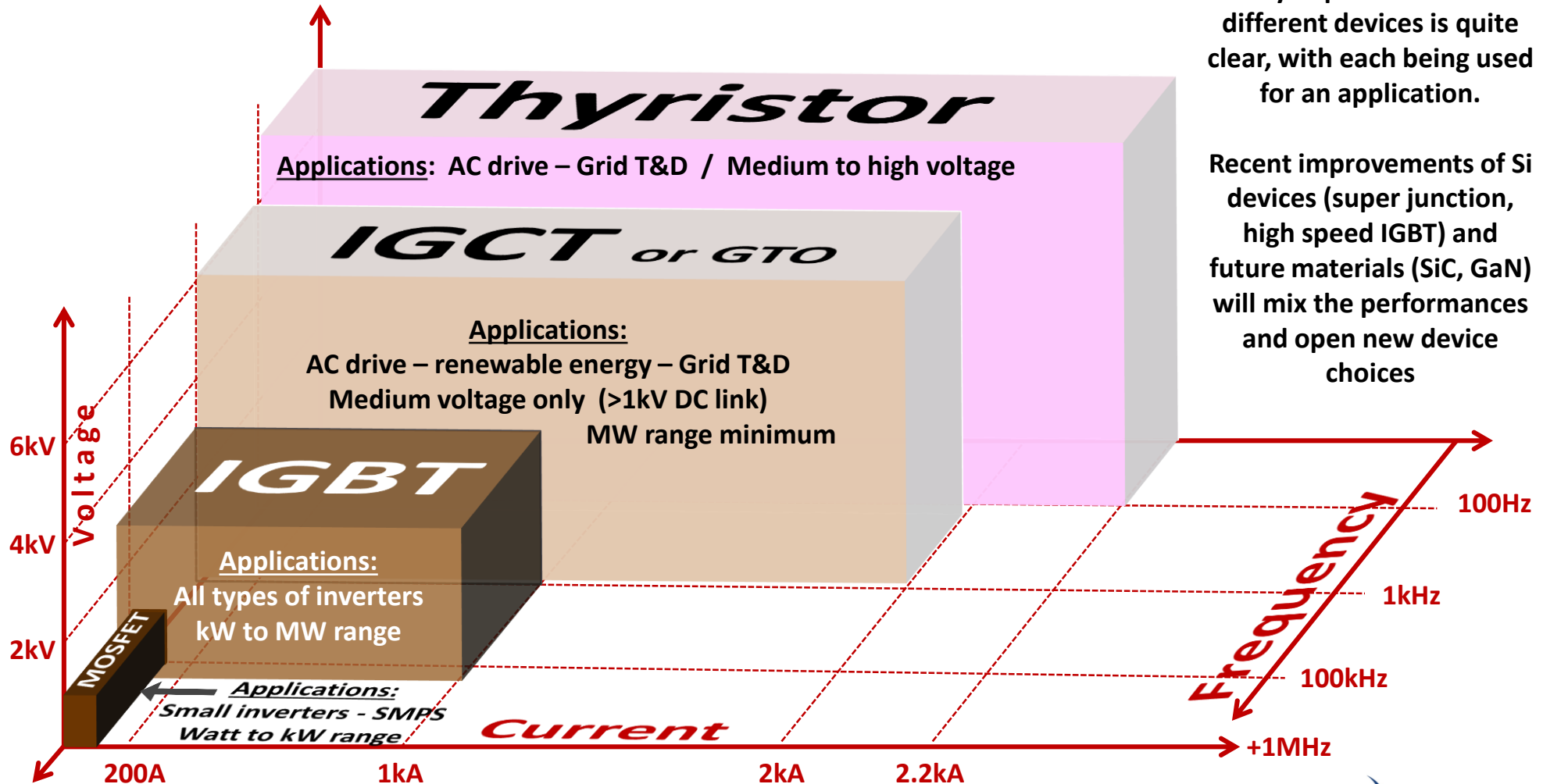
# Content of the webcast

- **Introduction: Status of the industry**
- **Main trends impacting the IGBT market evolution**
  - The power stack trend
  - The revolution of the Chinese IGBT
  - The growth of IGBT use in consumer applications
  - The competition from SiC and GaN based devices
- **Market metrics and conclusions**
- **Q&A session**

# **INTRODUCTION: STATUS OF THE INDUSTRY**

# Introduction

## Power semiconductor devices



Today's split between the different devices is quite clear, with each being used for an application.

Recent improvements of Si devices (super junction, high speed IGBT) and future materials (SiC, GaN) will mix the performances and open new device choices

# Introduction

*Life-cycle of power device technologies*

A new generation every ~20 years...

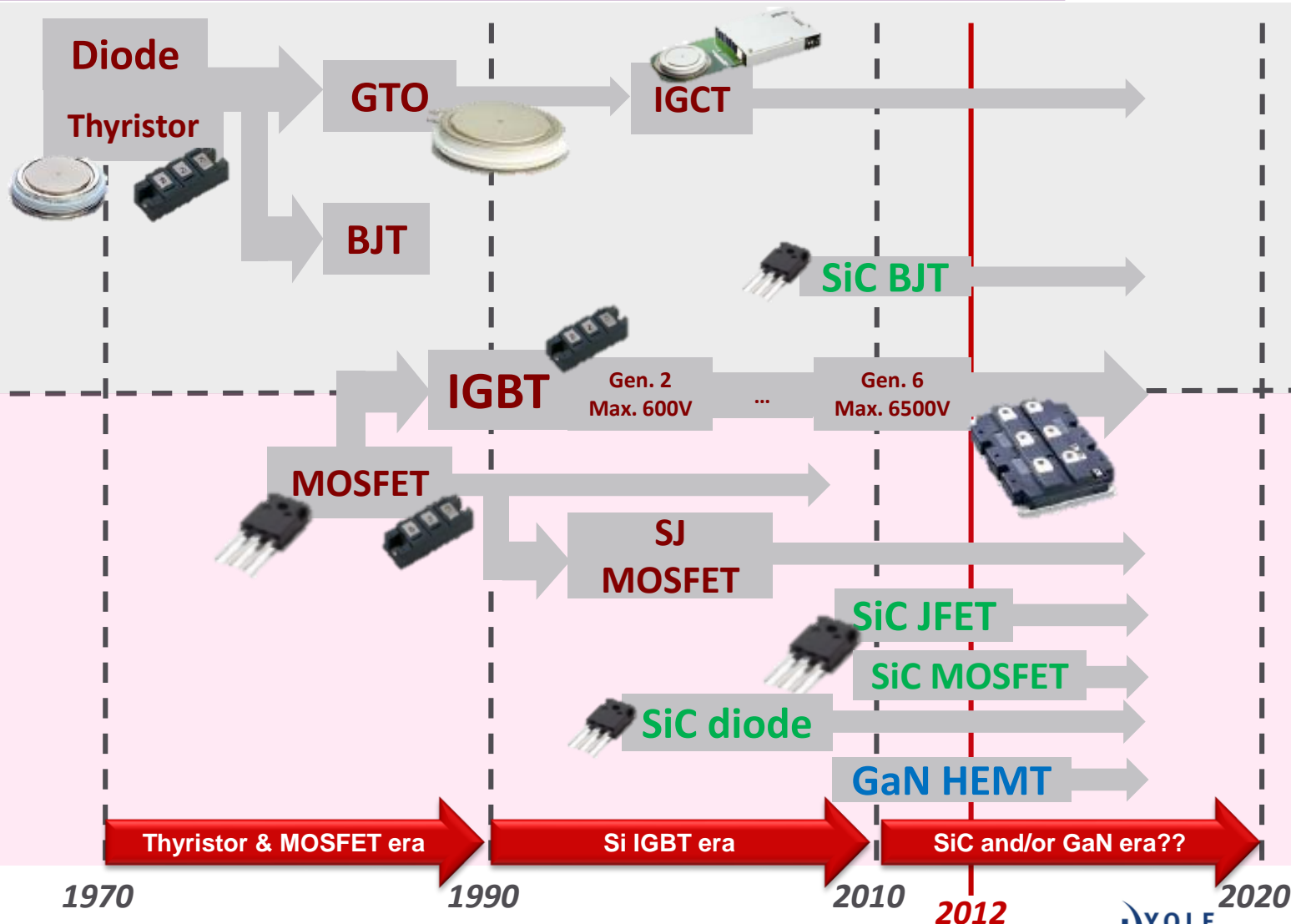
Silicon

SiC

GaN

Bipolar

Unipolar  
Field Effect Transistors



# Introduction

## Definition

## Device types

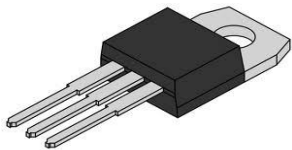
### Segmentation used for market forecast and analysis

- **Discrete**

- TO-220
- TO-247

Discrete components can be with or without diodes.

They are not widely used in motor drives. IPMs are cheaper and easy to integrate



- **IPM**

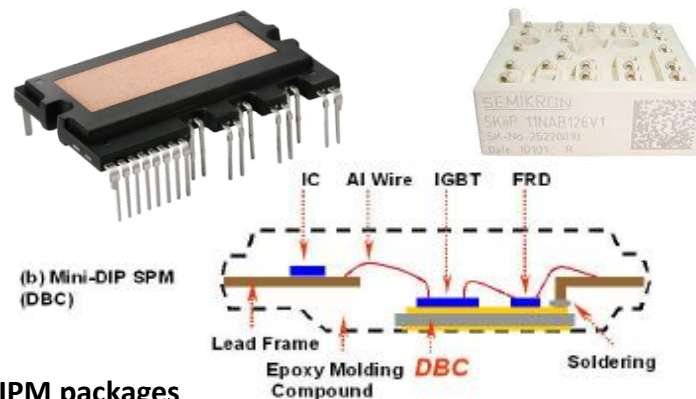
- **Two main types:**

- Molded and frame package
- They are in the same category for market forecasts

IPM is the widespread solution for motor drive. It is an all-in-one:

- IGBTs
- Diodes
- Drivers
- Protection

For motor drives, they are 6in1, 7in1 or 7in1+rectifier. Some companies also offer active PFC



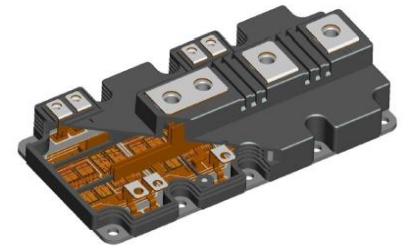
Molded IPM packages

Courtesy of Fairchild and Semikron

- **Modules**

Modules are used in every industrial application, with higher power. As Drivers cannot be integrated and higher heat must be dissipated, IPM cannot be used in over ~100kW drives

For motor drives, they can be 2in1, 6in1 or 7in1



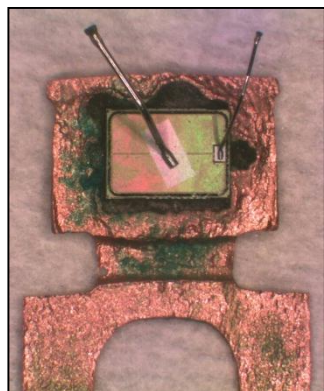
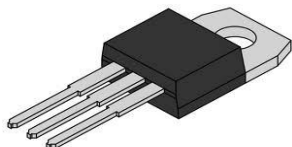
# Introduction

## Definition

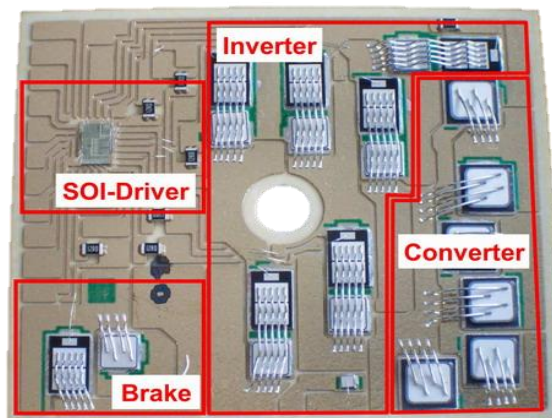
## Device types

*Segmentation used for market forecast and analysis*

### Discrete



### IPM

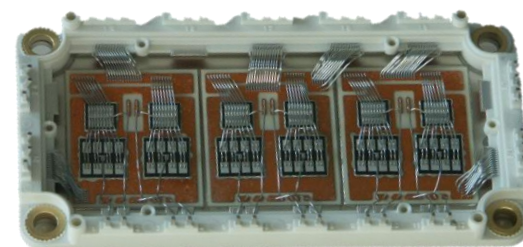
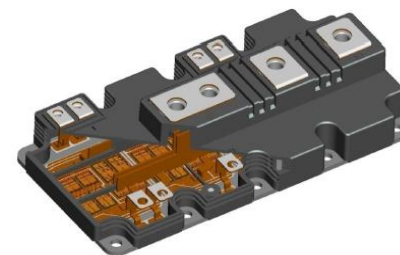


Source: Semikron

Example of IPM DCB board including:

- Inverter (IGBT+diode)
- Converter (Diode bridge)
- Brake (Chopper)
- Driver (made on SOI die to reduce size)

### Modules



Example of an IGBT module:

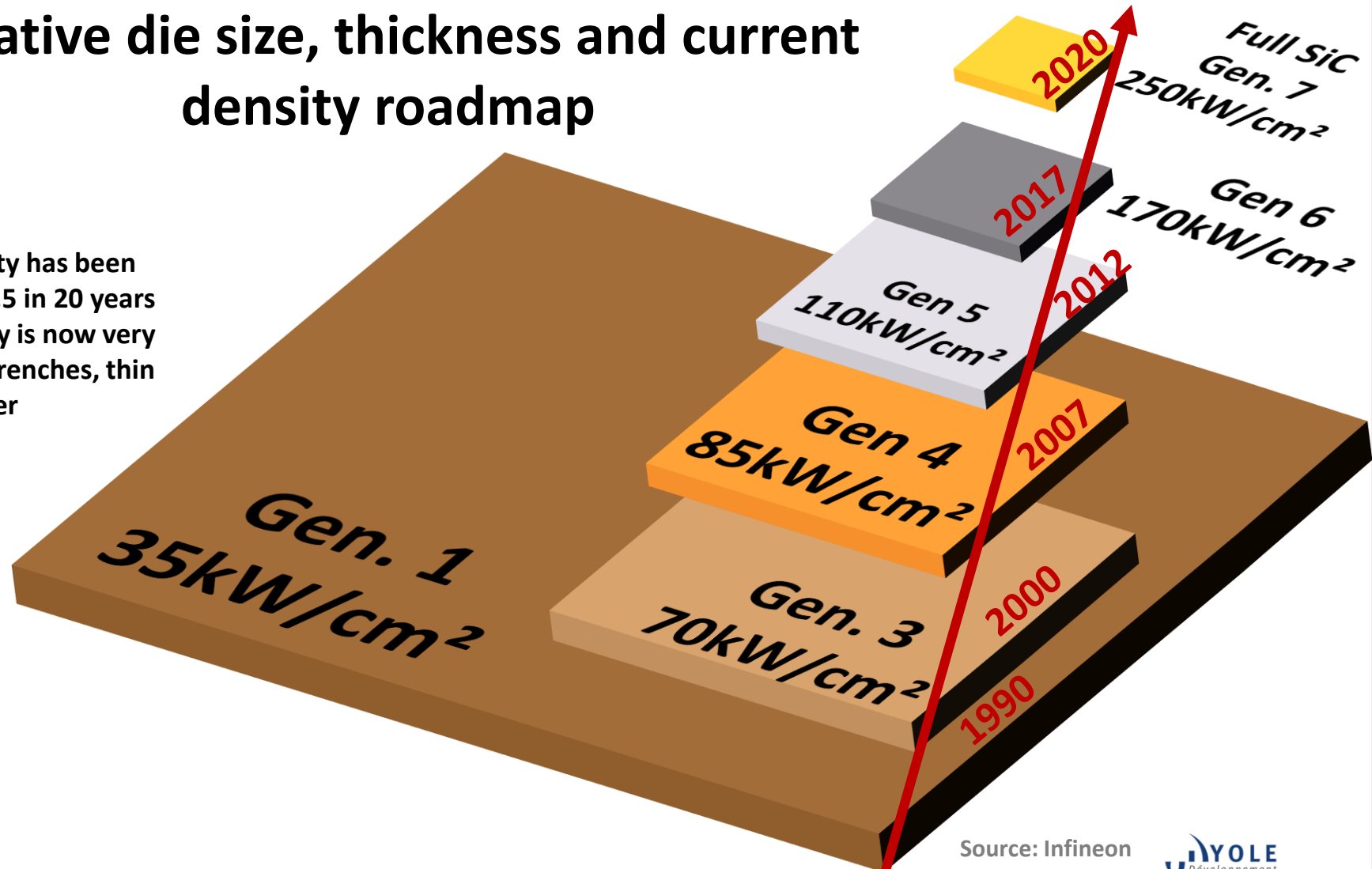
- IGBT+diode – 3phase

# Introduction

## IGBT current density trend

### Relative die size, thickness and current density roadmap

Current density has been multiplied by 3.5 in 20 years  
IGBT technology is now very mature, using trenches, thin wafer



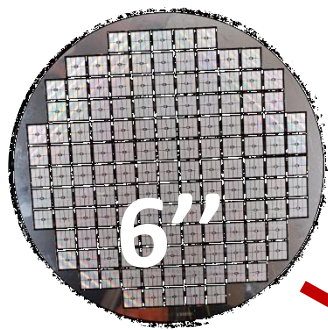
Source: Infineon



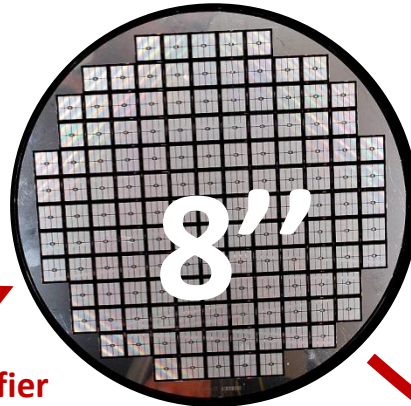
# Introduction

## *Wafer size – split by player*

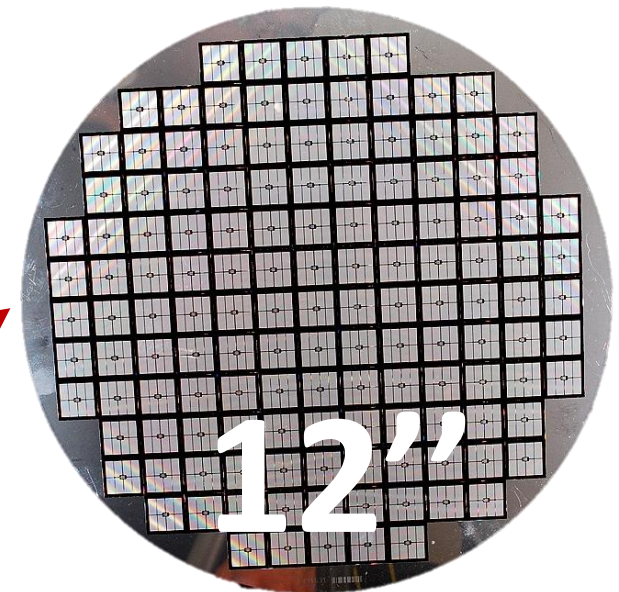
- Wafer size for IGBT production is still growing, and Infineon is now the leader.
- Infineon expects a cost advantage of 20-30%, by increasing the wafer size from 8 to 12 inch.
  - For Infineon 12 inch production line is for MOSFETs, they will probably produce IGBT 600V on thin wafer.
  - Fairchild and International rectifier prefer to stay on 8 inch and consolidate production yield



- International rectifier
- ON semiconductor
- Rohm



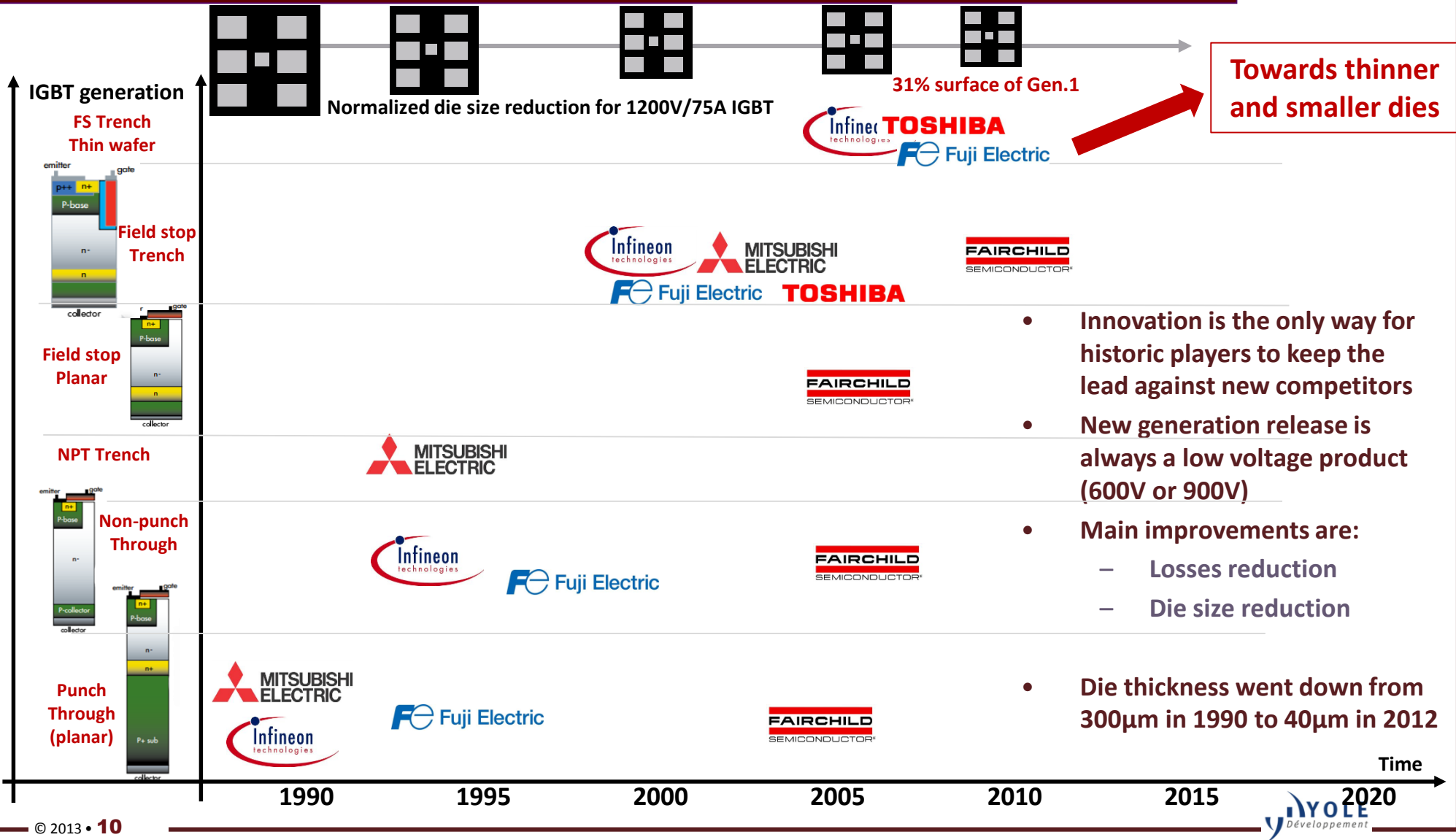
- Fairchild
- Toshiba
- Fuji electric
- Mitsubishi
- Renesas



- Infineon

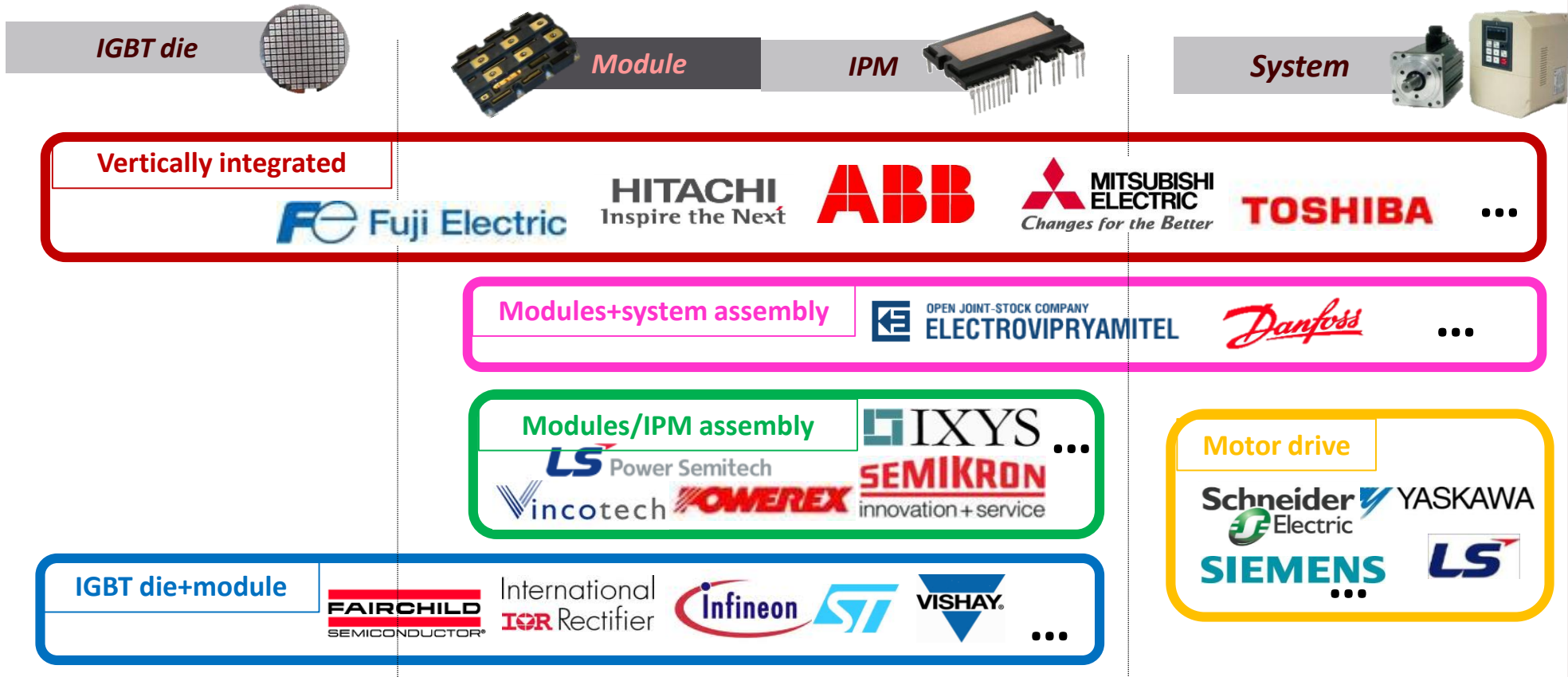
# Introduction

## Technology roadmap for IGBT



# Introduction

## IGBT market supply-chain



- **Vertically integrated companies are Japanese only**, besides a few (like ABB...)
- Only a few companies (like Danfoss) take advantage of doing module and inverter for motor drives. In cost driven market, there is not much competitive advantage in developing its own module.

# Introduction

## IGBT market supply-chain

### Design

### Die manufacturing

### Packaging

Module-discrete-IPM



Fabless



Foundries

MagnaChip® in 2013 ?

华虹-NEC in 2013 ?

Shanghai Hua Hong NEC



GRACE SEMICONDUCTOR in 2013 ?

MANUFACTURING CORPORATION

+ Others...



DAWIN Electronics



Others...

# MAIN TRENDS IMPACTING THE IGBT MARKET EVOLUTION

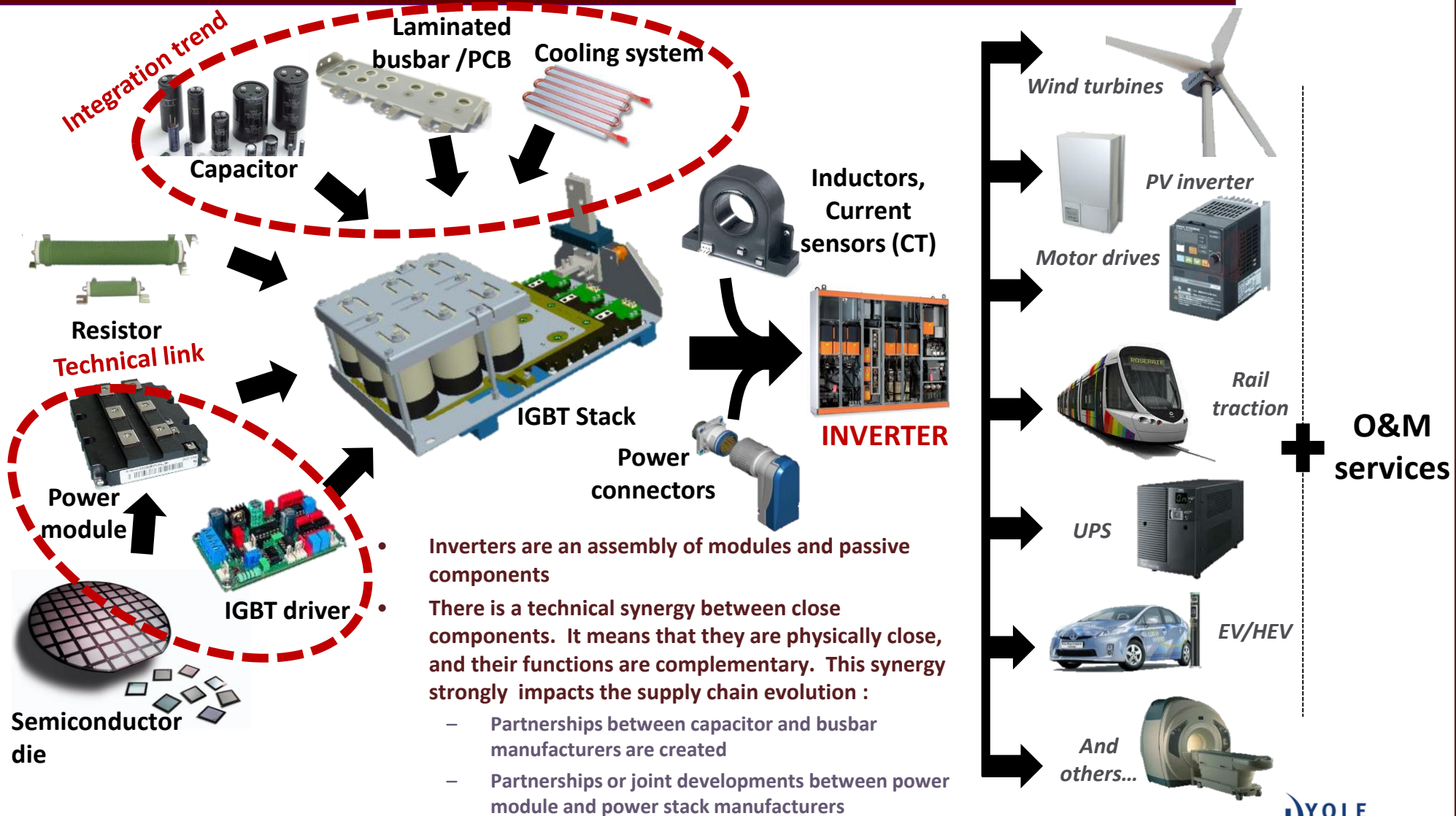
# Main trends impacting the IGBT market evolution

- There are several main trends, at system level or at supply chain level that will reshape the IGBT industry. This chapter illustrates these trends:
  - **The power stack trend:** the need for more modularity and higher performance made components maker (active and passive) to join and create consortium or JV's
  - **The revolution of the Chinese IGBT:** First Chinese companies are starting to manufacture IGBTs: Standard technology and low cost, thus perfect for a local market
  - **The growth of IGBT use in consumer applications:** IGBT are becoming more and more part of consumer life: Renewable energies and EV/HEV are examples of this. Also they are more and more used in home appliances: there is an “inverterization trend”. This create a opportunities that many players get ready to take
  - **The competition from SiC and GaN:** The next generation devices are becoming available. They will displace IGBT, but not at all levels and in all applications



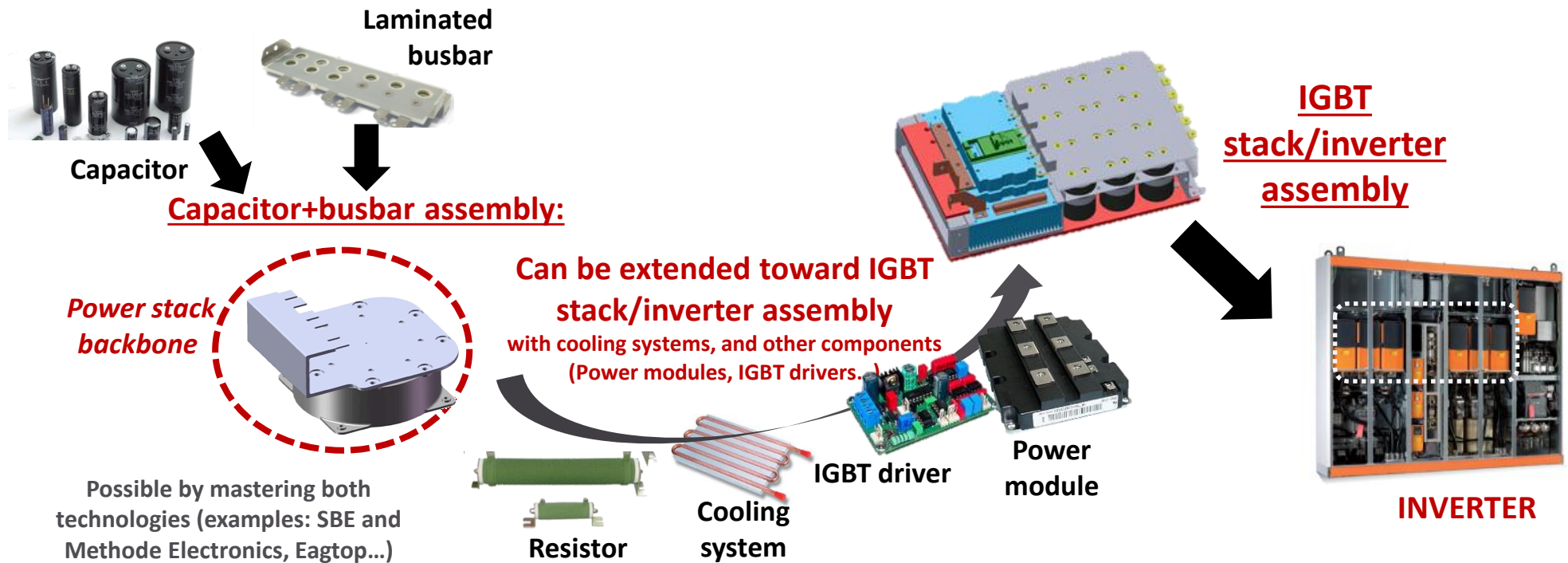
# The power stack trend

*What is a power stack and where are integration opportunities*



# The power stack trend

## *Towards more integration*



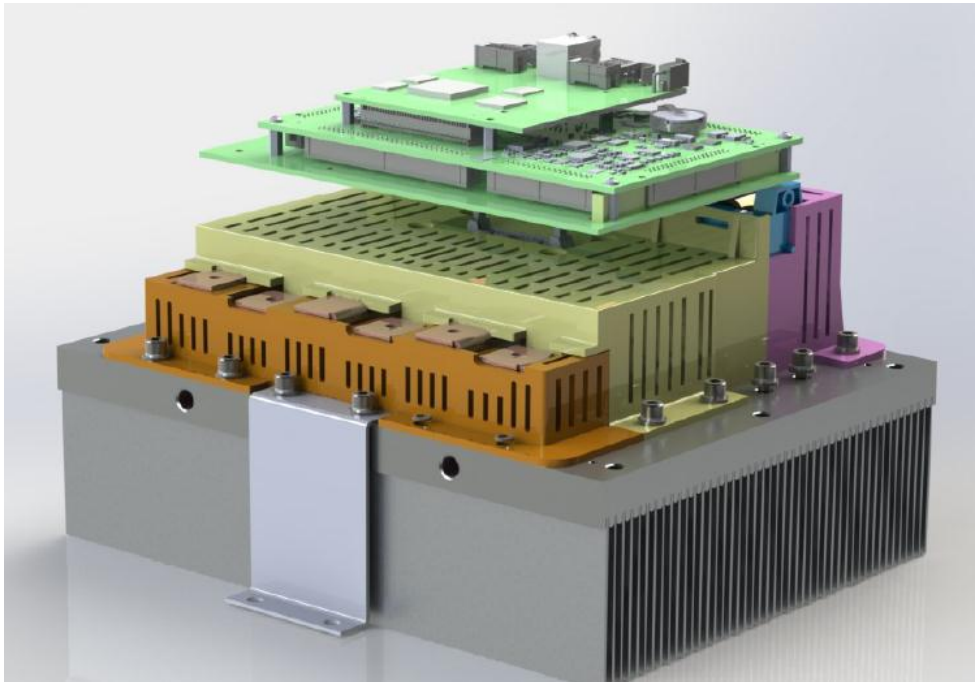
- **Passive components can also be pre-assembled:**
  - Capacitor + Busbar are already integrated by some companies, we identified this as a technical and supply chain trend. This concept can be extended, including power modules, IGBT drivers, cooling, power modules.



# The power stack trend

## *Case study: the smart power stack consortium*

- Methode, SBE, AgileSwitch and Fuji electric have announced their alliance in a consortium
- According to our feedbacks, this is a development, marketing and commercial partnership, with no exclusivity



• **Busbar:**



• **Power module:**



• **IGBT driver:**



• **Controller:**



• **Capacitor :**



**All US based companies**

# The revolution of the Chinese IGBT

## *Chinese players on the road to IGBT manufacturing*

- Asian players are becoming a greater part of the IGBT market. They still do not manufacture a lot of devices. But we expect them to quickly gain market shares in low cost local businesses



# The revolution of the Chinese IGBT

## *New entrants in IGBT chip manufacturing market*

Company	Date of entry or announcement	Short profile
CSMC	2011	Chinese foundry. Subsidiary of CRmicro Ltd.
Hua-Hong NEC	2011	Chinese foundry. formerly JV of Hua-Hong and NEC
Grace semiconductor	?	Chinese foundry. IGBT capability to be confirmed
Alpha & Omega semiconductor	2011	Fabless (development and design only).
Phoenix semiconductor (PSMC)	?	Chinese fab for discrete.
BYD	?	Working on 1200V IGBT for vertical integration in EV/HEV
CSR – times electric	2010	Became manufacturer with acquisition of Dynex
NXP	?	Rumors of NXP coming back to the IGBT manufacturing (They also posted job offers going that way)

# The revolution of the Chinese IGBT

## *Conclusions*

- In conclusion, many Chinese companies are very close or already able to manufacture their own IGBTs. This will grow and will create a Chinese IGBT:
  - We expect this market to be focusing on production for local assembly: small power and low cost systems
  - The historic players (Infineon, Mistubishi, Fuji electric...) will keep on innovating to stay ahead of this new competition. They will supply IGBTs for high-end products and industrial solutions requiring specific or even custom needs

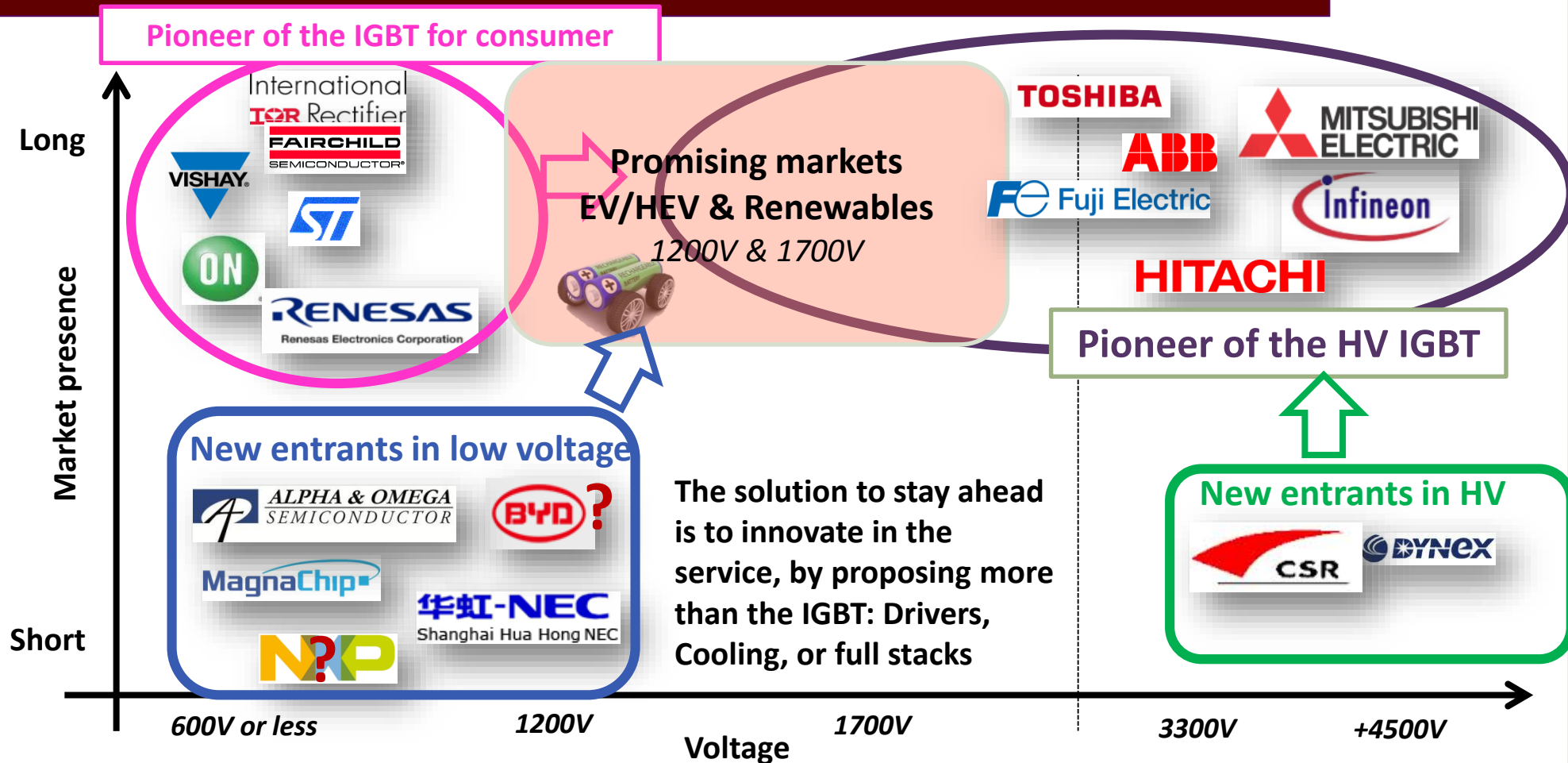
# The growth of IGBT use in consumer applications

## *Introduction*

- **We observe an increase of the use of IGBTs in consumer applications:**
  - Higher power consumer markets as EV/HEV and renewable energies with residential PV and small wind turbines in the future
    - This pushes for price accessible low and medium power inverters, with high conversion performances
  - Home appliances moving to inverter based conversion. Washing machines, refrigerators, induction cooking...
    - This pushes for low cost IGBTs or IPM; specifically made for these applications
- This trend is also changing the rules, as an industrial market does not have the same requirements and needs as a consumer market

# The growth of IGBT use in consumer applications

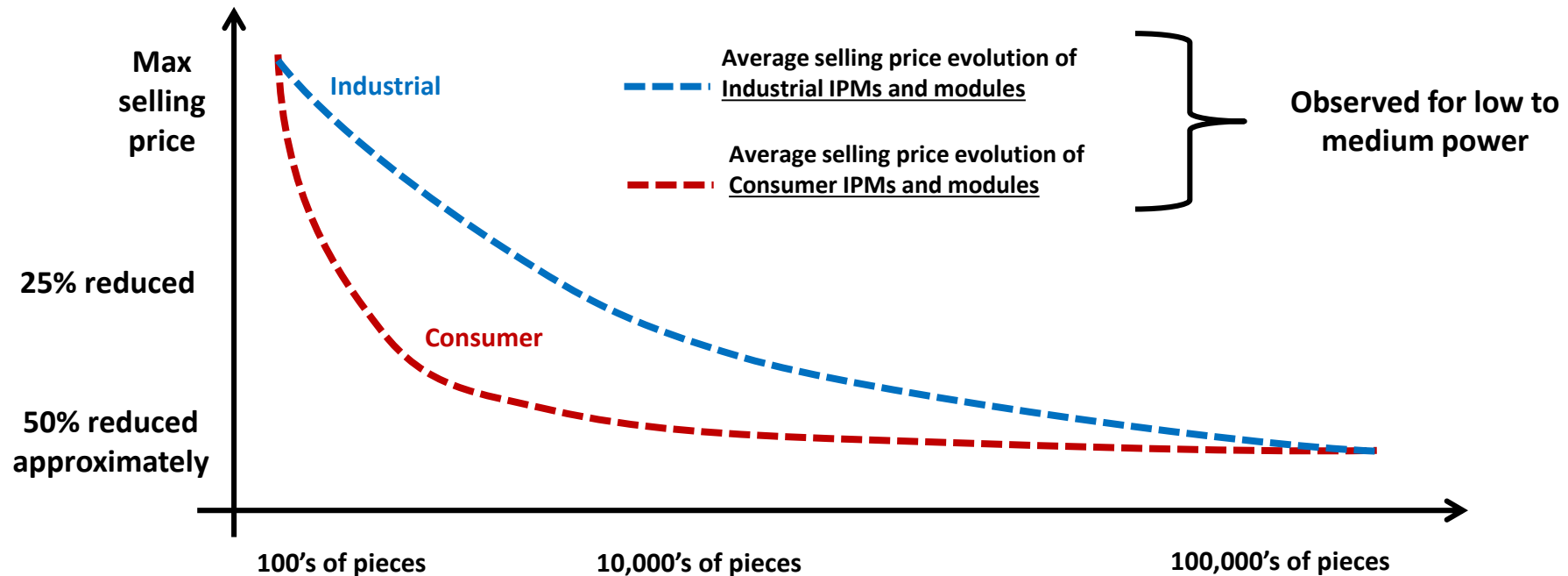
## IGBT Players landscape analysis



- Pioneers of the HV IGBT have the best market shares. Margin for HV IGBT modules is high and their historic position made them first in the promising markets as EV/HEV and Renewables
- New markets are targeted by all players, and only the strongest or the smartest will survive

# The growth of IGBT use in consumer applications

*ASP evolution difference regarding application type*



- **ASP evolution of consumer markets drop down very fast compared to industrial markets:**
  - Cost pressure is strong in industrial segments, but even stronger in consumer applications
  - This cost pressure added to volume manufacturing, has made possible the design of specific modules (IPM, 7in1, integrated rectifier...) to reduce production and assembly cost
  - Orders to build industrial systems are generally smaller than the ones for consumer systems. This explains greatly this curve. Most of the orders for consumer systems are in the more than 10,000 pieces range

# The growth of IGBT use in consumer applications

## *Case Study: A package for EV/HEV applications*

- DLB is for Direct lead bonding. It is a specific technology made by Mitsubishi Electric to manufacture epoxy molded power modules for hybrid and electric cars:
  - Instead of Al wire, a lead connects the IGBT dies to the Inputs/Outputs
  - A lead is rigid, thus the soldering must replace the flexibility of the wire. This stays a and issue Mitsubishi had to overcome
  - Mass production is planned in 2013, but already used since 2011
  - Target is automotive (600V/600A modules)

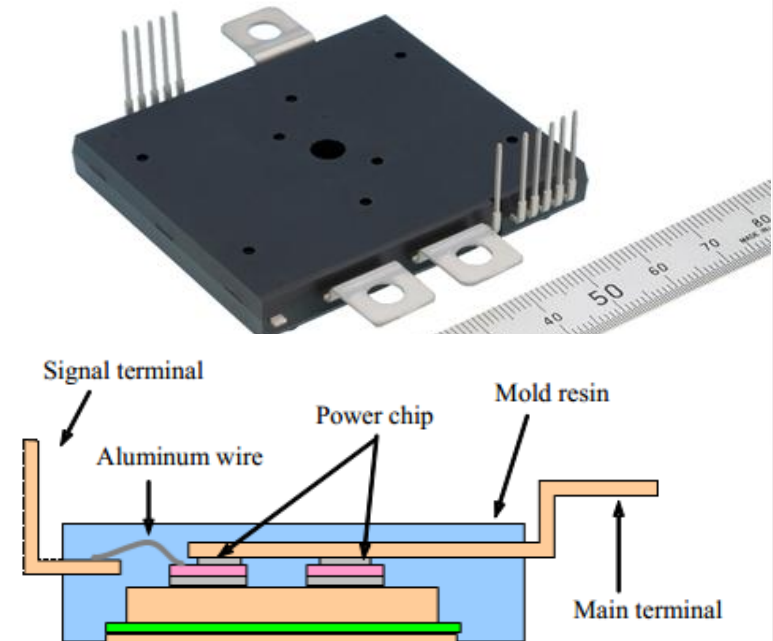
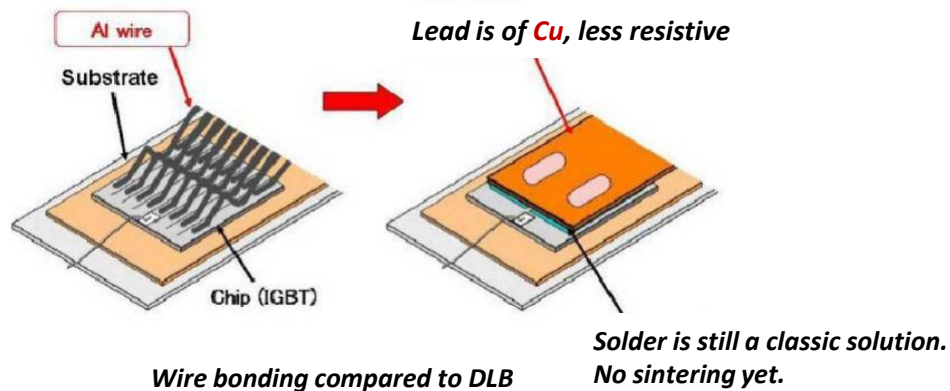


Figure 1: DLB structure

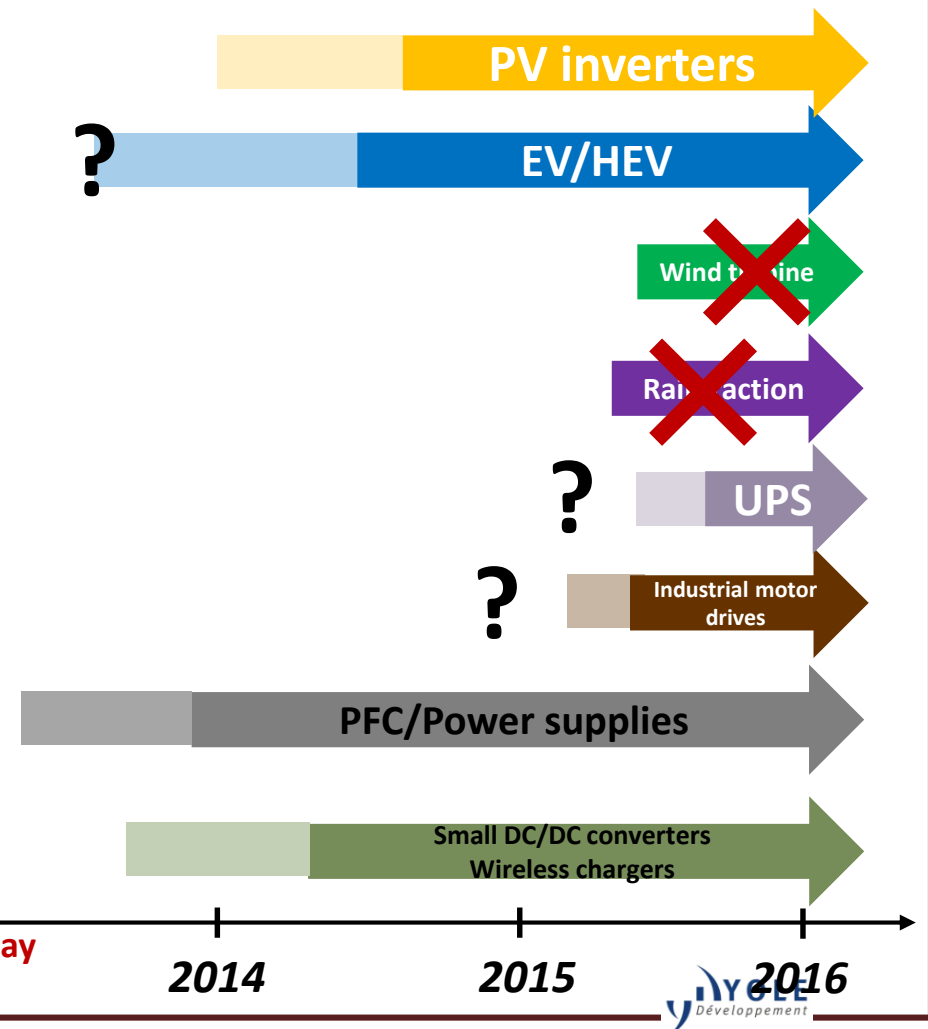


# The competition from SiC and GaN

## Implementation of GaN Materials in Power Electronics

Diode Switch

- Characteristics of GaN-based inverters will be:
  - They will primarily target medium voltage applications (in the 200 – 600V range)
  - We expect GaN to penetrate the over-600V market one to two years later than we estimated in the previous report
  - GaN targeted applications will be very different from SiC, at first. We will observe a competition in PV inverters, and potent

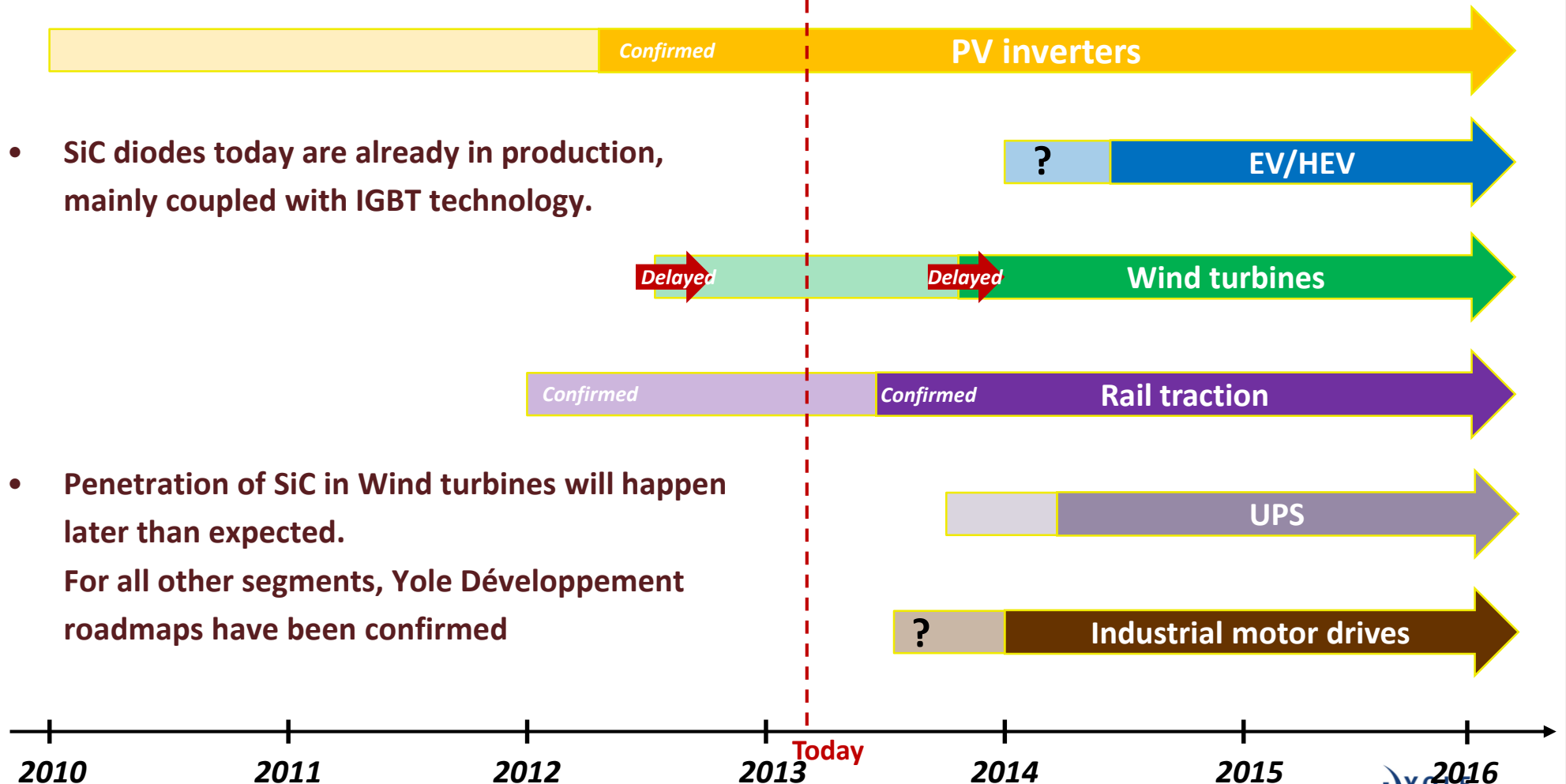


# The competition from SiC and GaN

## Implementation of SiC Materials in Power Electronics

Diode Switch

*Remark: Extract from 2011 Yole Développement analysis updated to show realizations and delays*

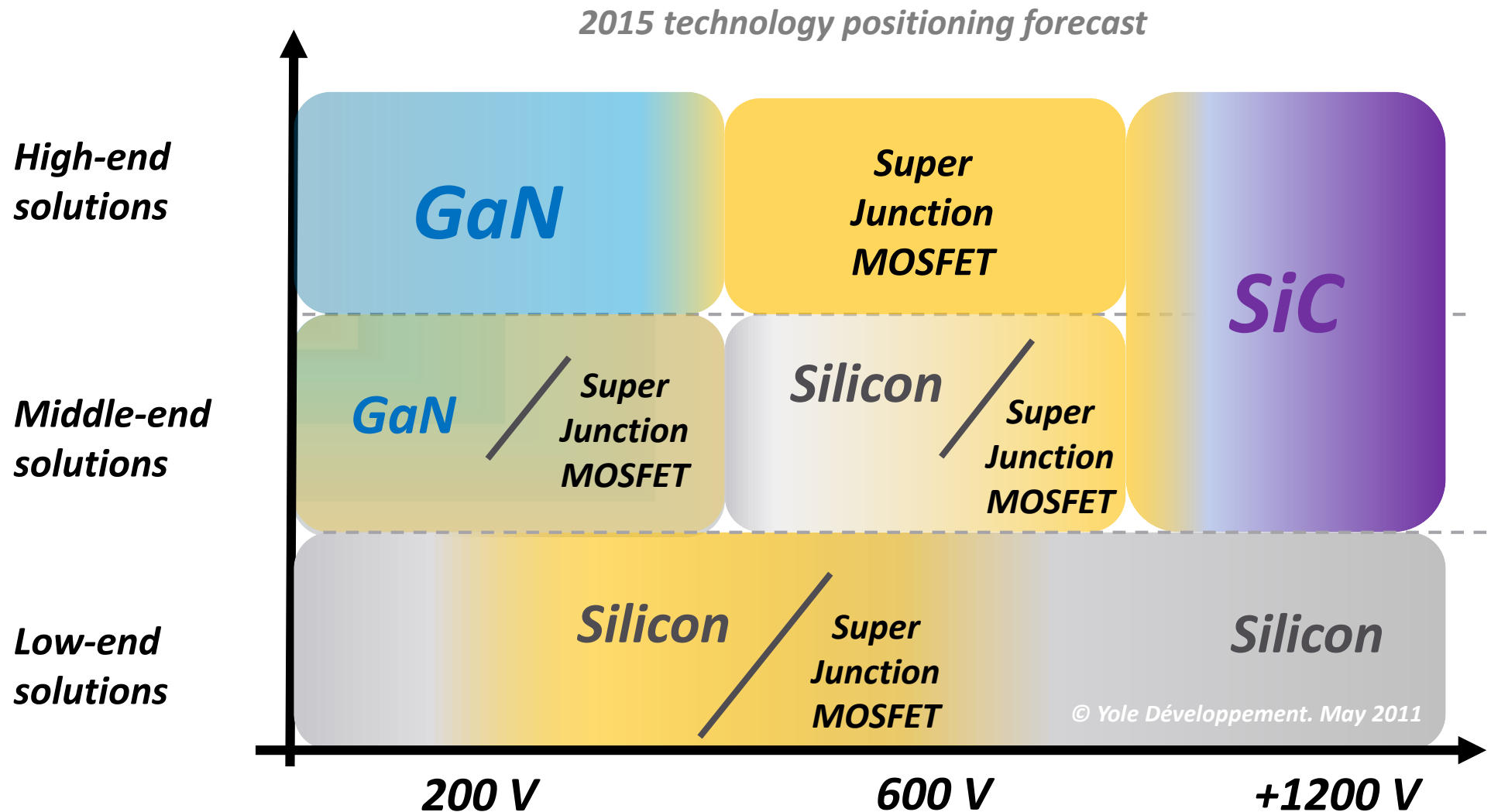


- SiC diodes today are already in production, mainly coupled with IGBT technology.

- Penetration of SiC in Wind turbines will happen later than expected.  
For all other segments, Yole Développement roadmaps have been confirmed

# The competition from SiC and GaN

*Technology positioning - 2015 forecast*

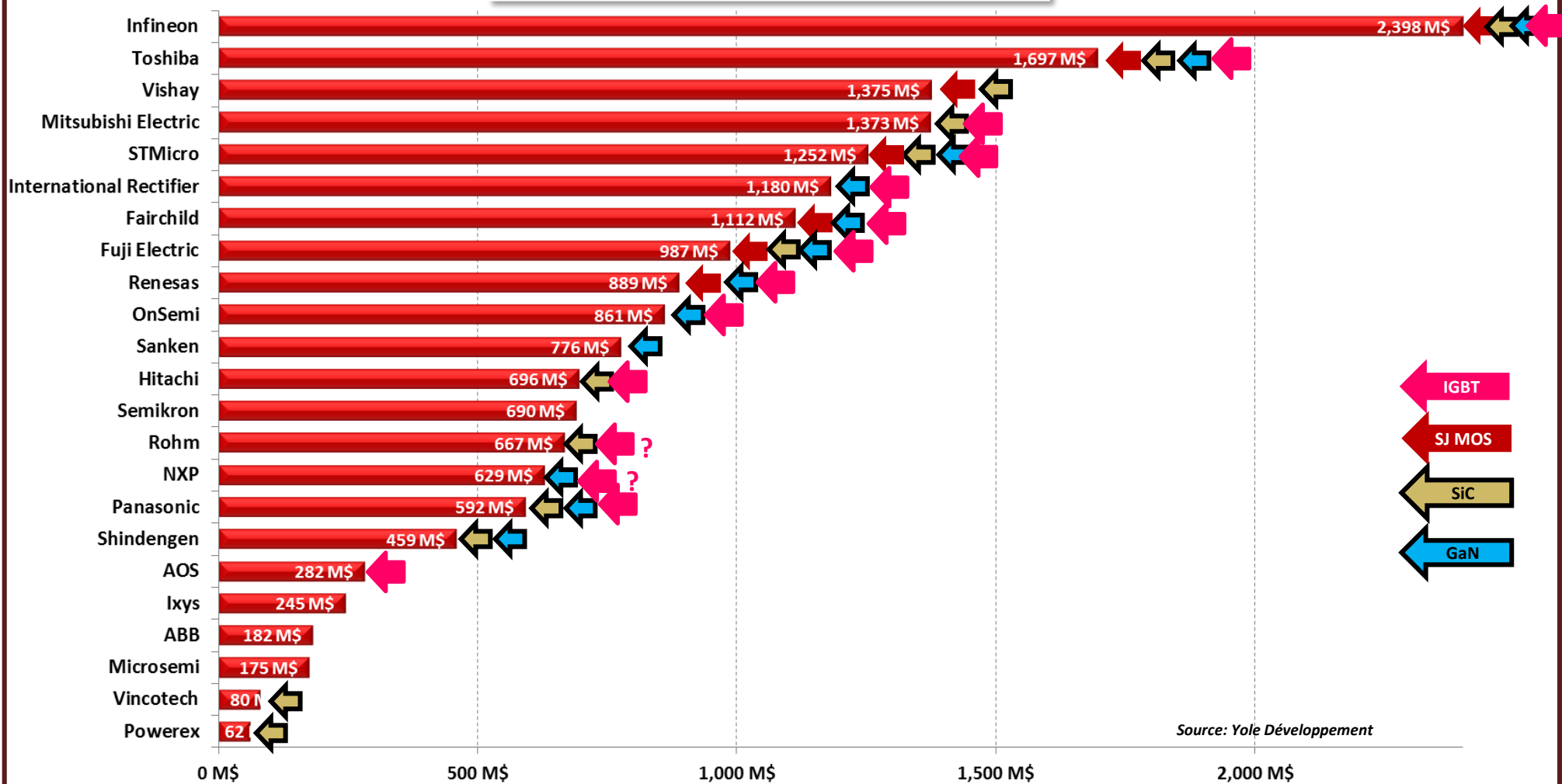


# MARKET METRICS AND CONCLUSIONS

# Market metrics and conclusions

## Top-20 Power Semiconductor

TOP-23 2011 power company revenues

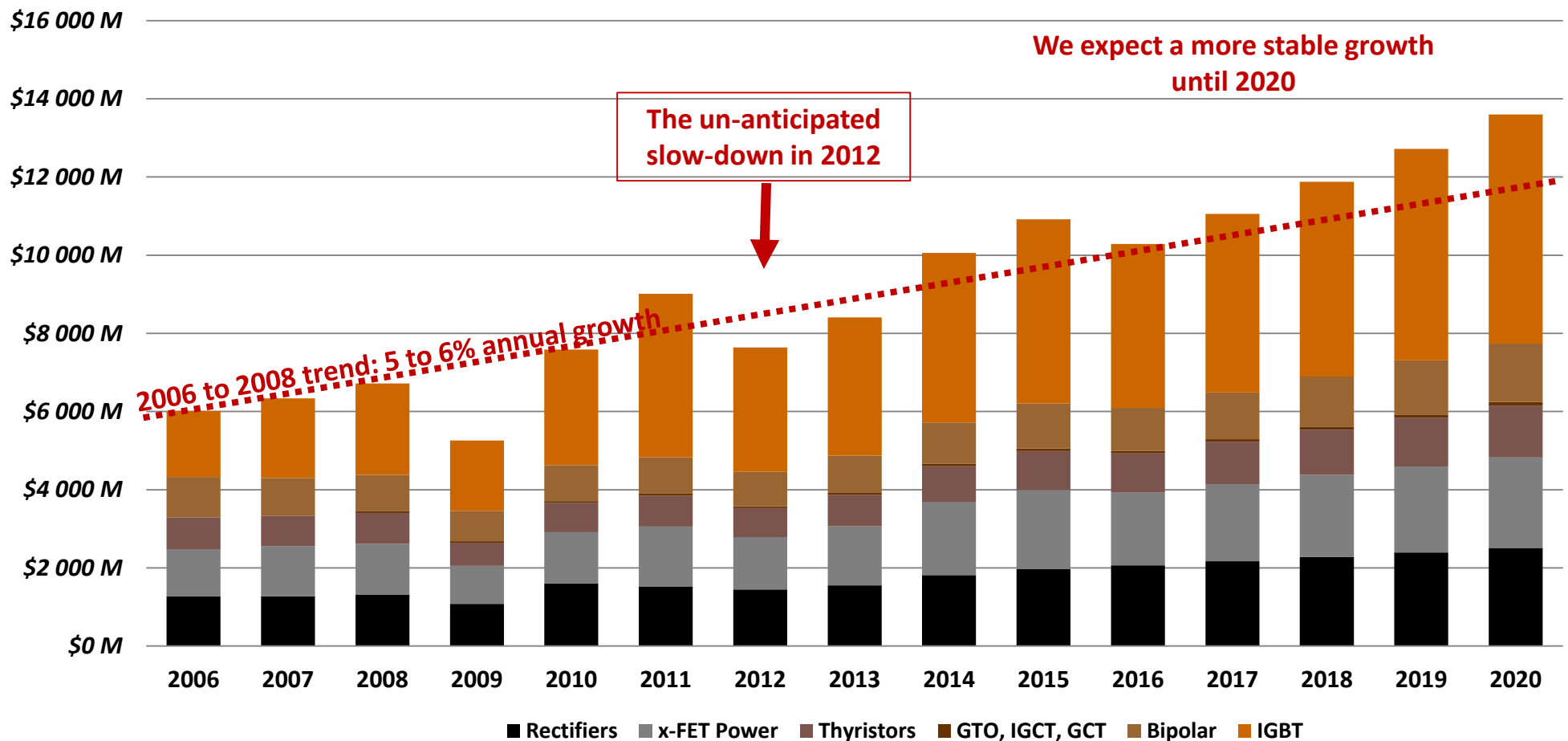


Source: Yole Développement

# Market metrics and Conclusions

## Power devices market forecast

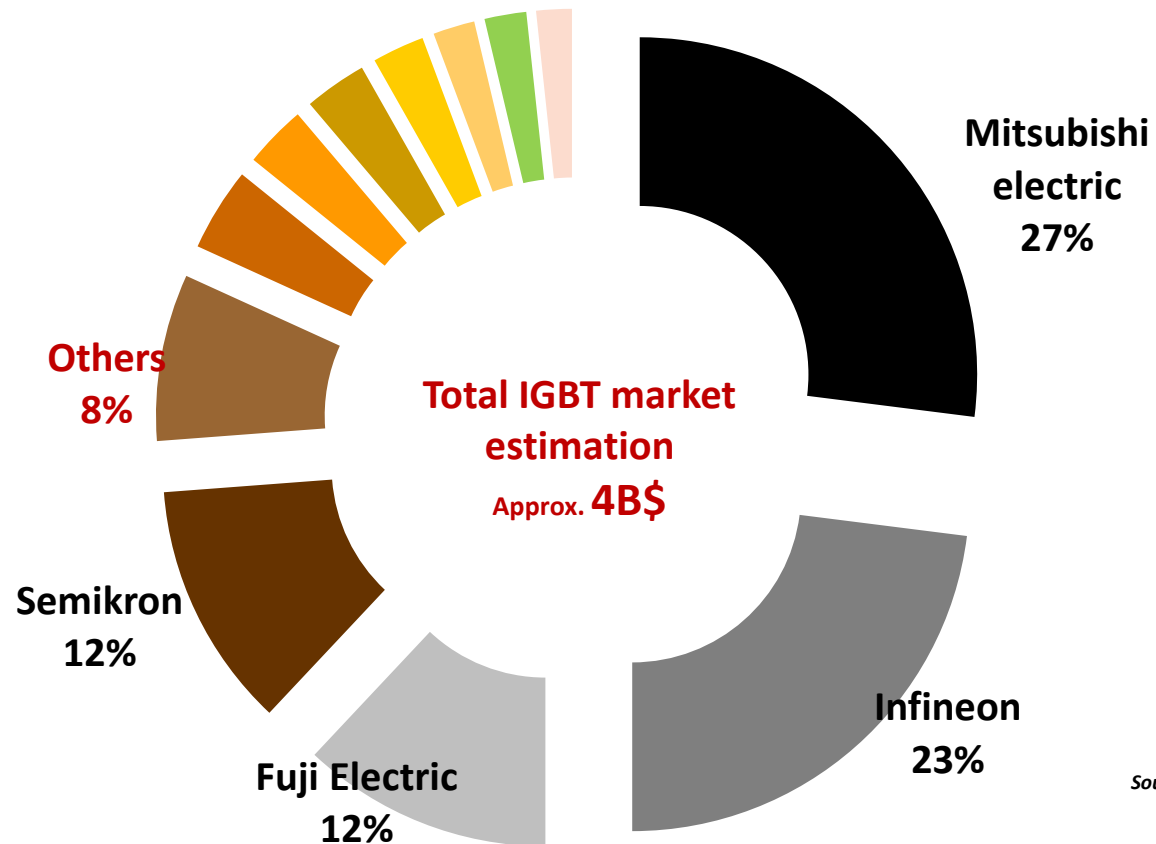
### 2006-2020 Market size for power devices



Source: Yole Développement, WSTS

## IGBT manufacturers market shares

## 2011 estimated IGBT players market shares

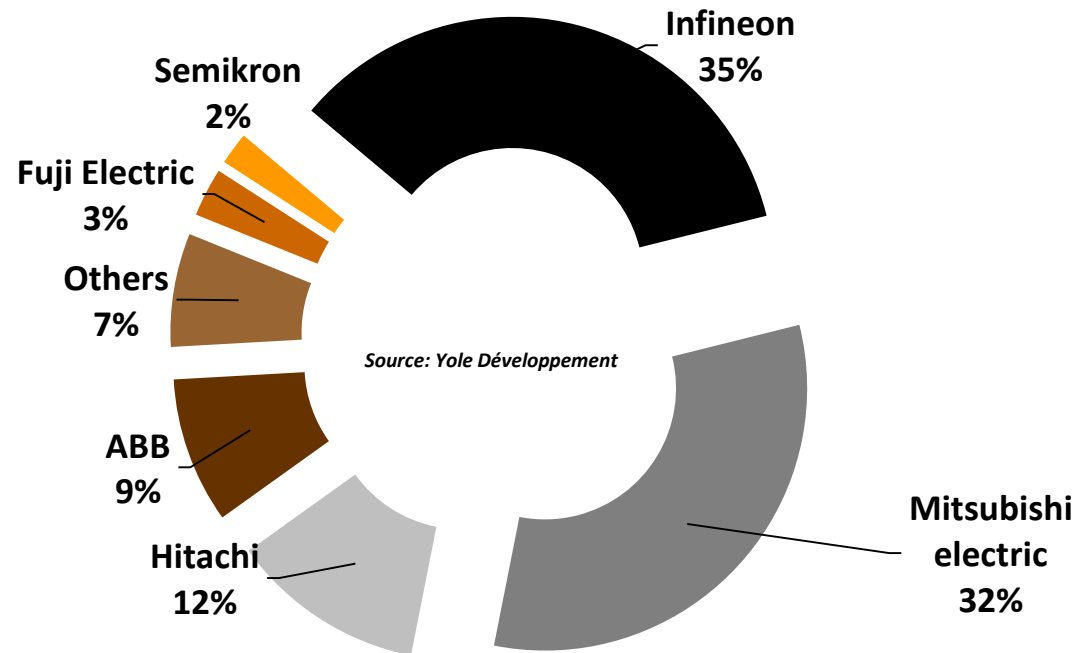


**Source: Yole Développement**

# Players production analysis

## *IGBT manufacturers market shares*

### Players market shares for >1.2kV IGBT

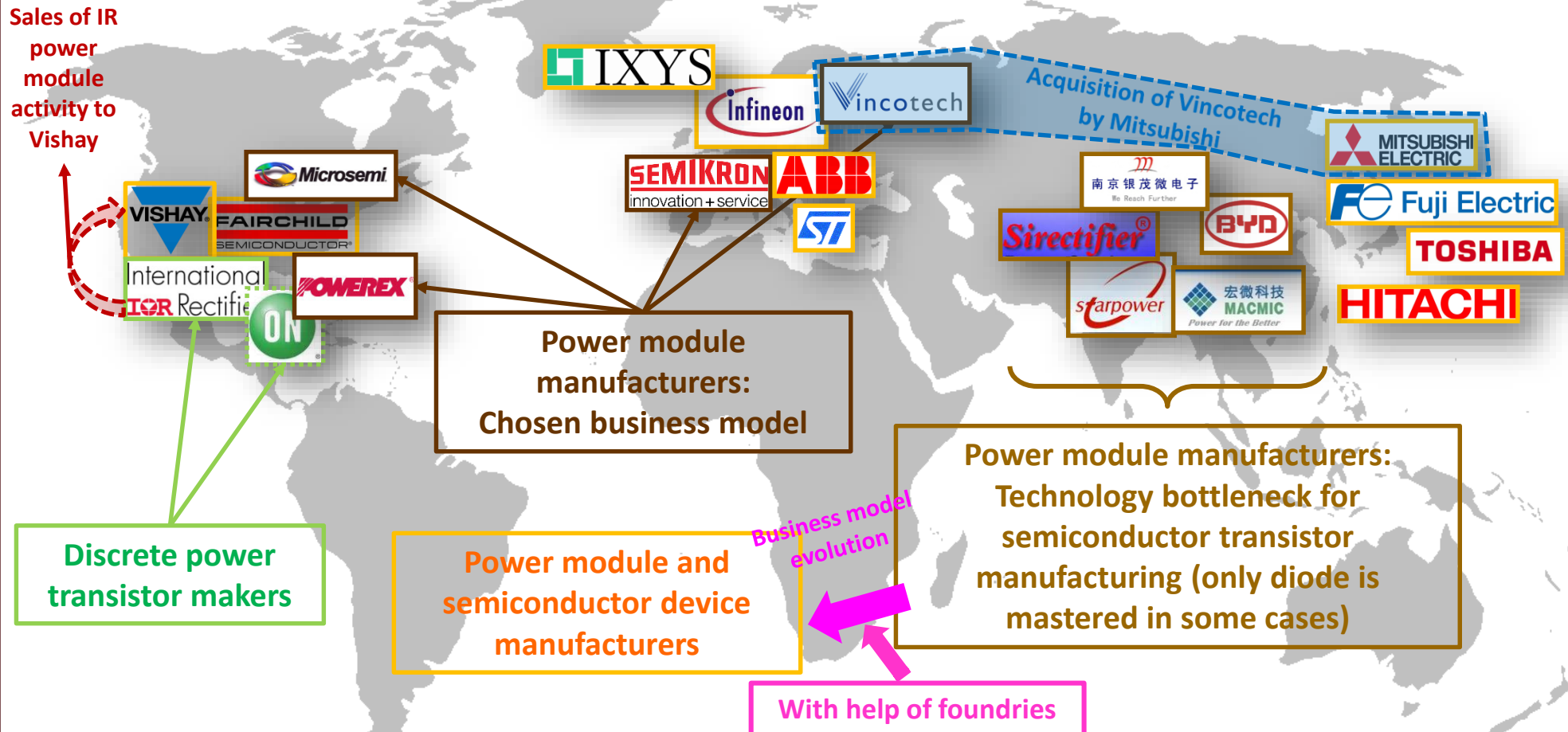


- High voltage IGBT modules leaders are Mitsubishi and Infineon. Hitachi is thought to follow.
- ABB focus on its own technology with IGCT.
- Among others are companies like Dynex...



# Semiconductor evolutions – IGBT

## Power Module Players Typology

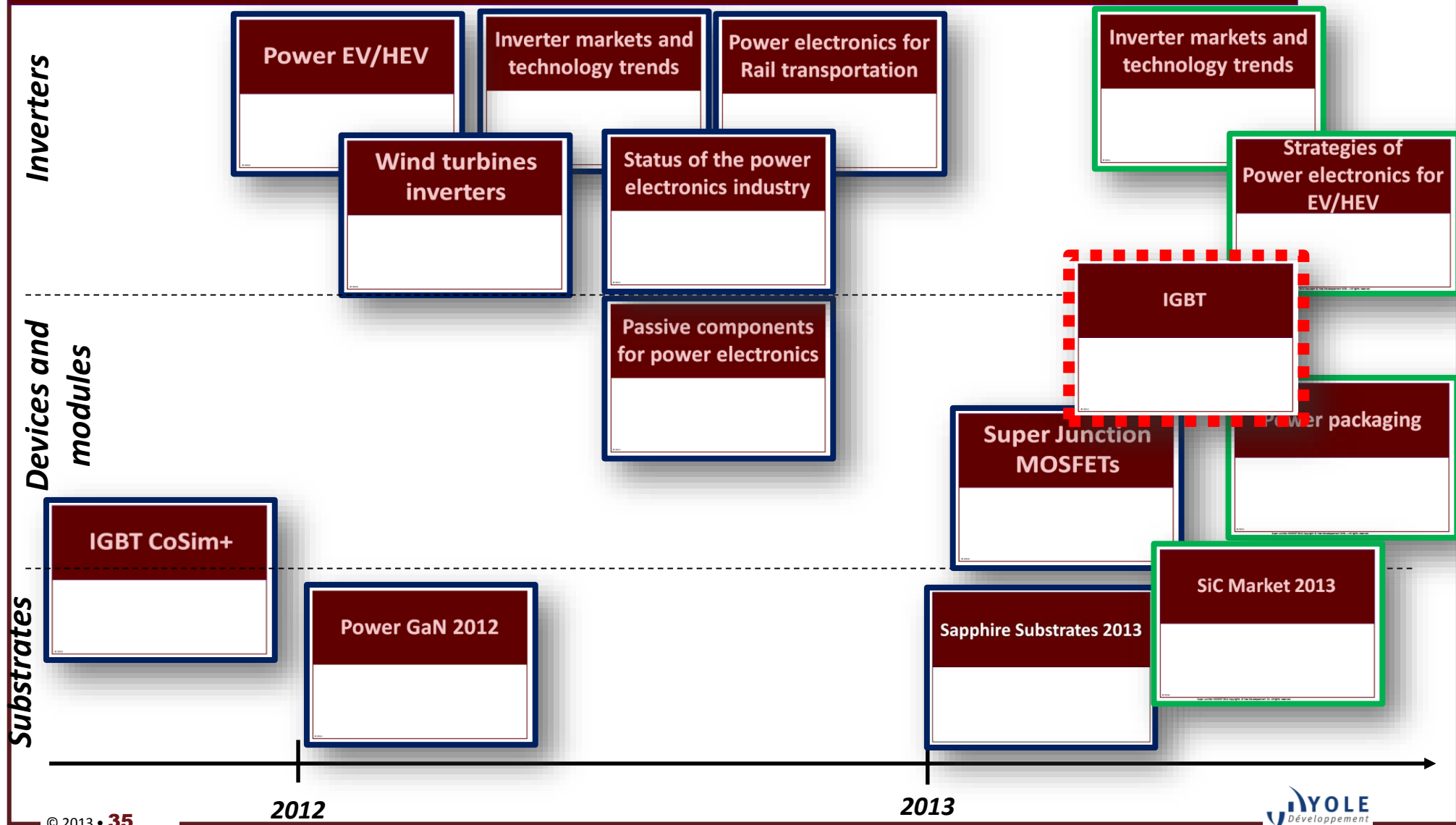


*We estimate that about 15 companies (foundries, fablights and fabs) are working on IGBT development in China*

# General conclusion

- This webcast gave a quick overview of what are the new trends that will impact IGBT markets
- We presented a lot of different trends at different level of the supply chain:
  - The main idea is to see how all these trends are related and dependent one to the other and impacting one on the other. The key point is then to see which is impacting the most each companies business
  - There seems to be a slow down of the IGBT market in 2012. We believe it's only due to a misunderstanding and lack of anticipation of the recent economics evolutions. We are very confident in this market growth. Energy production, distribution and use is the next challenge for this world. Power semiconductor is the heart of this challenge
- A deeper and complete analysis is available in our report about IGBT, SiC or GaN markets, as well as inverters and power electronics applications

# Yole power electronics reports in time



# Yole power electronics reports in time

## Questions are welcome

**SAVE THE DATE**

### Power Electronics Market Briefing

A power electronics market and technology briefing on IGBT

**May 15, 2013**  
**From 1:30 PM to 3:30 PM**  
*In the Forum Area*

**FREE ENTRANCE**

For more information, please contact C. Favre (favre@yole.fr)

**SPEAKERS:**

- **Henning M. Hauenstein**, VP and General Manager, Automotive Products Business Unit, International Rectifier Corporation
- **Asif Jakwani**, BU Director, Power Discrete, ON Semiconductor
- **Alexandre Avron**, Market & Technology Analyst, Yole Développement

### Your contacts at YOLE Développement:

– **Philippe ROUSSEL**, Business Unit Manager, Power Electronics, Compound Semiconductors

- Email: [rousseau@yole.fr](mailto:rousseau@yole.fr)
- Tel: +33 472 83 01 86

– **Alexandre AVRON**, Technology and Market analyst in Power Electronics

- Email: [avron@yole.fr](mailto:avron@yole.fr)
- Tel: +33 472 83 01 03

– **Jerôme AZEMAR**, Technology and Market analyst in Power Electronics

- Email: [azemar@yole.fr](mailto:azemar@yole.fr)
- Tel: +33 472 83 01 81