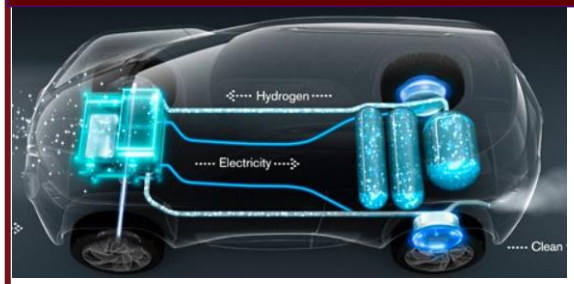
APEC 2015

EV-HEV Market and Technology Trends



Infineon

Toyota

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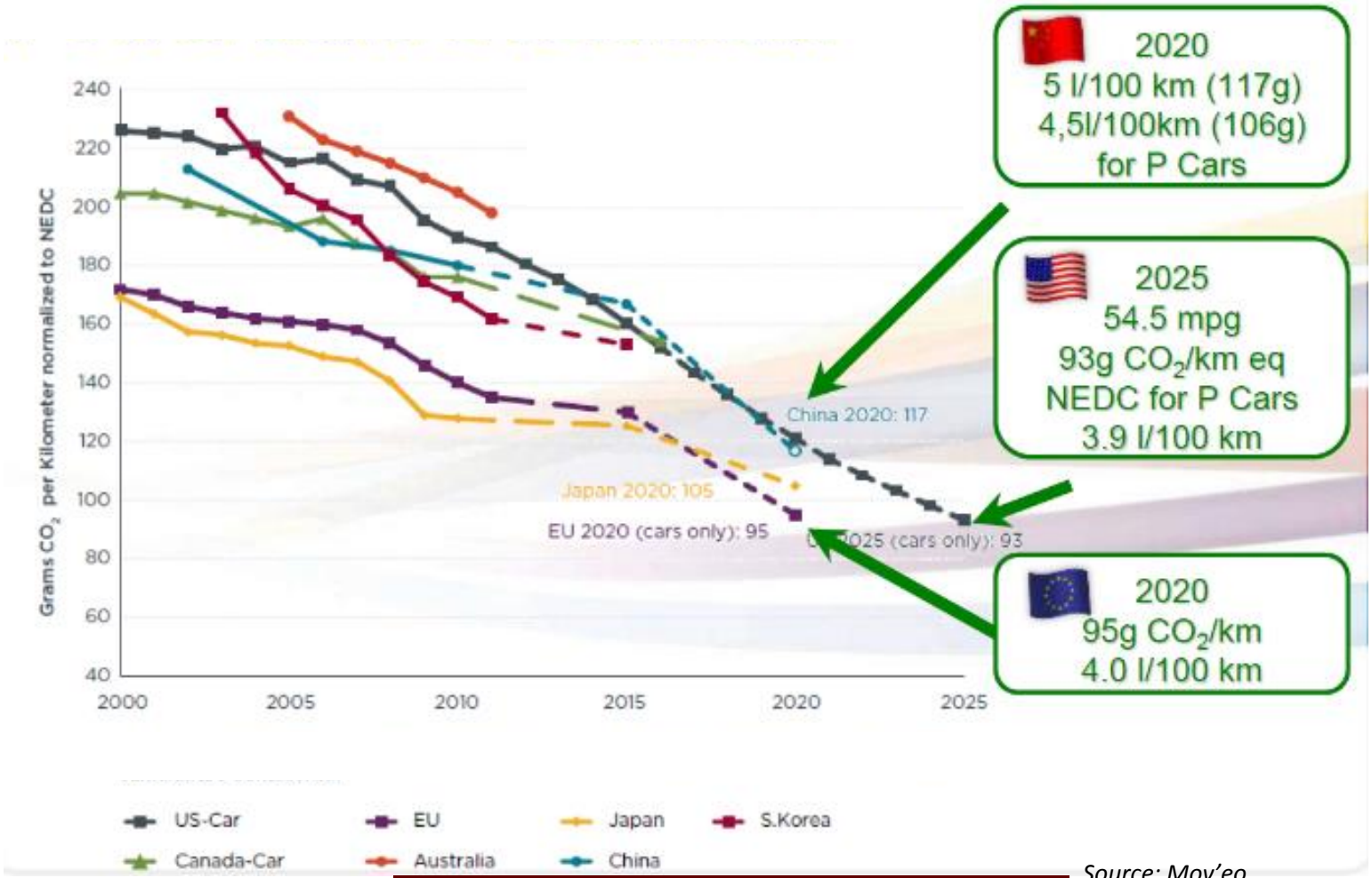
EV/HEV Market

EV/HEV market development: why and how?

Why developing electrified vehicles?

CO2 and pollution reduction

The strengthening CO_2 regulation is the <u>key driver</u> for the development of electrified vehicles.



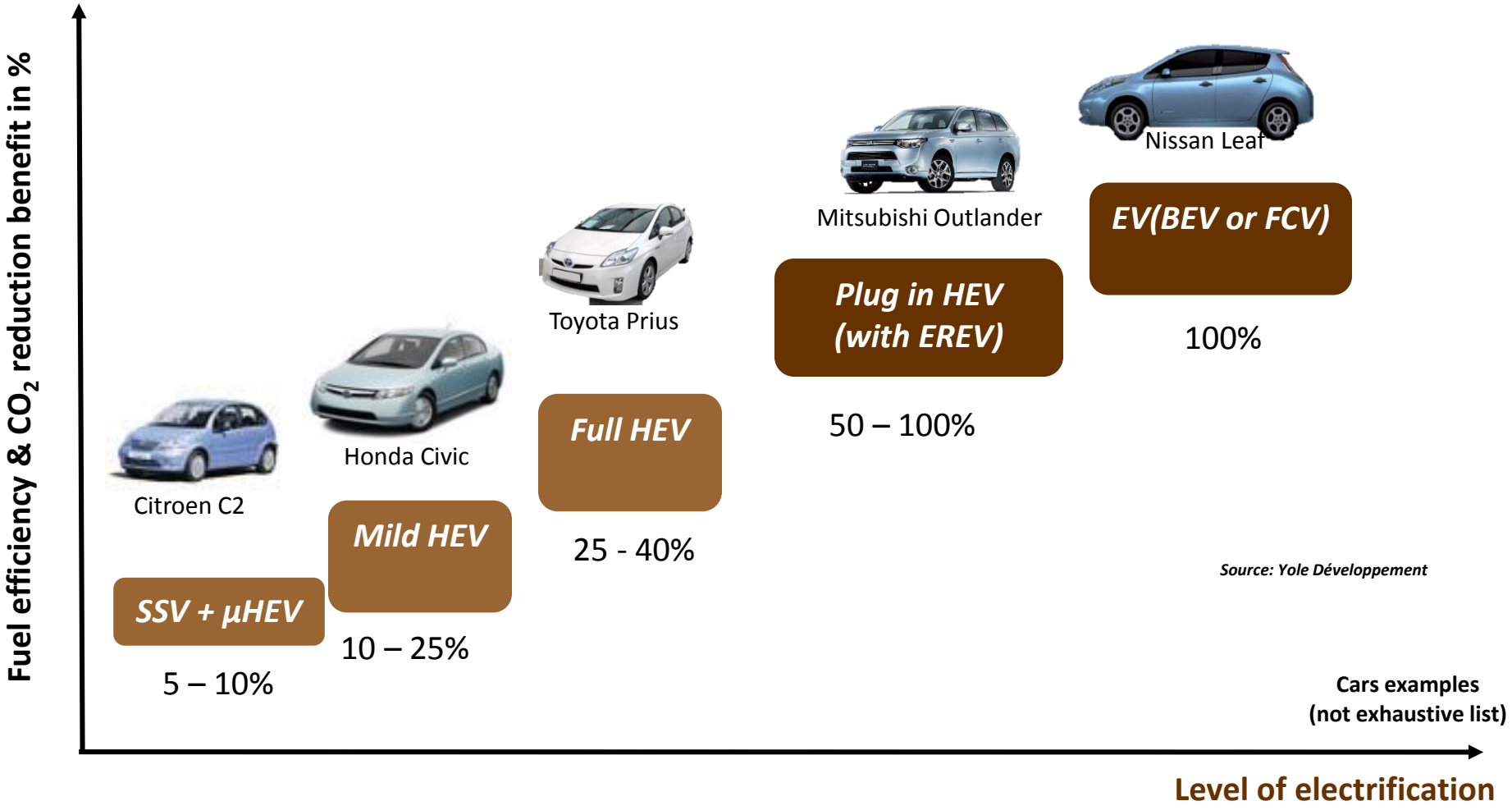
Source: Mov'eo

EV/HEV market development: why and how?

Different options to electrify vehicles

Definition of different electrified vehicles (1/2)

Different level of electrification exist to answer CO2 reduction targets



EV/HEV market development: why and how?

Different options to develop electrified vehicles

Definition of different electrified vehicles (2/2)

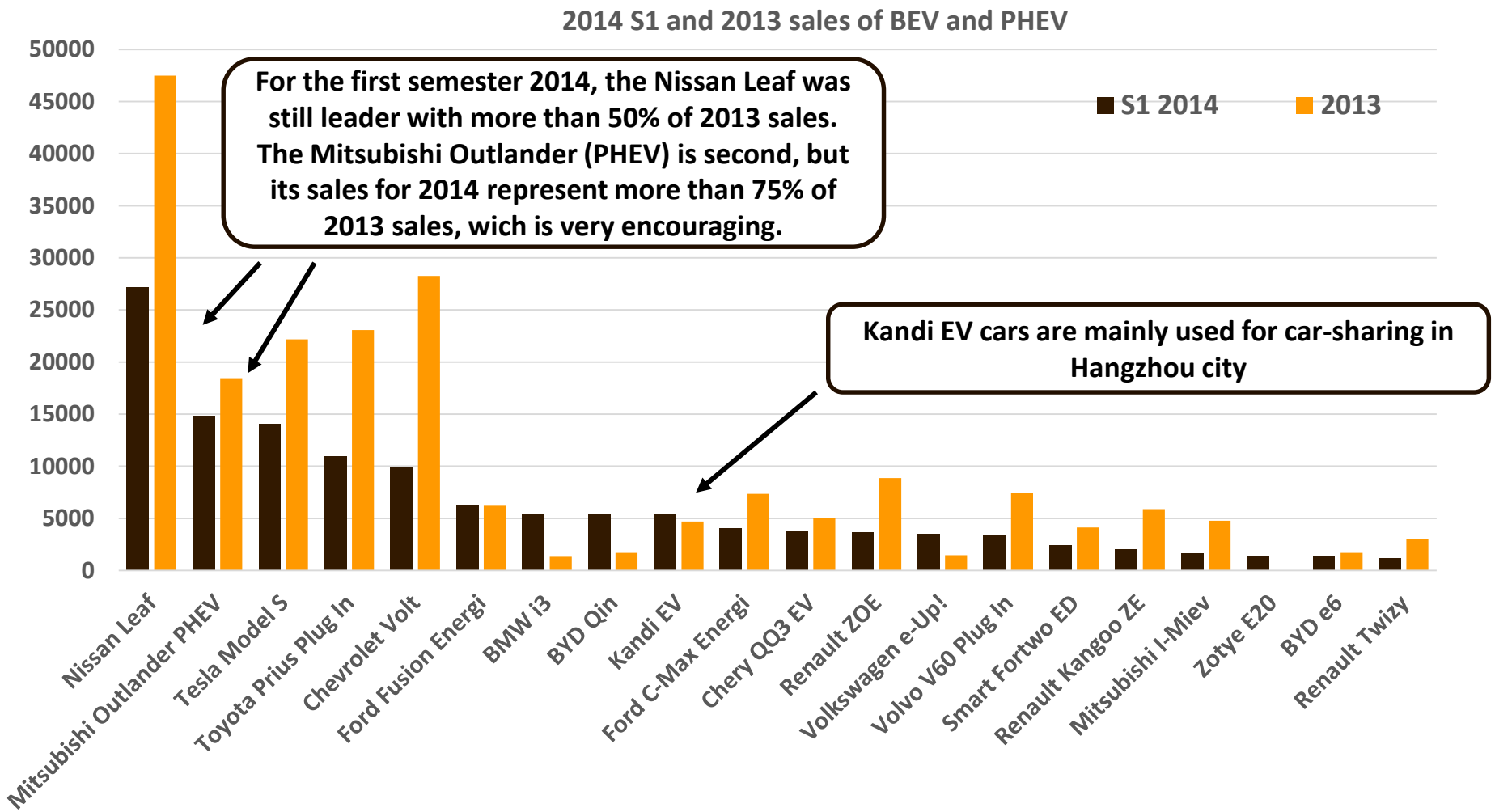
Functions	SSV + µHEV	Mild HEV	Full HEV	PHEV (with EREV)	EV (BEV or FCV)
Start/stop: stop engine idle when a vehicle slows down and comes to a stop	X	X	X	X	X
Regenerate braking		X	X	X	X
Additional power for a few seconds (electric motor)		X	X	X	X
Additional power for mid distance (city traffic)			X	X	X
Power for long distance (10 to 40 miles)			X	X	X
recharge battery on the grid or with a generator				X	X
Energy savings	5-10% (up to 25% in city traffic)	10- 25%	25 – 50%	50 – 100%	100%
Electric power	3-8 kW	4 - 20 kW	30 - 75 KW	70 – 100 kW	70 – 100 kW
Car example	PSA C2	Honda civic	Toyota Prius	GM Volt	Nissan leaf

Source: Yole Développement

EV/HEV market development: why and how?

EV sales worldwide in 2013 and S1 2014

Split by car models



EV/HEV Market

EV/HEV market development: why and how?

What slows down electrification

- Electrified vehicles market still has to overcome some difficulties to know a full development
- Price of electrified vehicles is often prohibitive for users; with technology continuous improvement and volumes increase, electrified vehicles should quickly reach thermic ones in terms of price
- Battery cost and autonomy is still a big obstacle to market advancement. Many projects have been launched to increase battery capacity worldwide and so to decrease battery cost. Moreover, many progress have been done on power density to reduce battery volume. In the coming years we expect battery cost to drop strongly and autonomy to increase greatly for a reasonable price
- With regulations coming from Governments, charging solutions should quickly come to a standard and infrastructure should develop a lot
- All those points that have to be improved for electric vehicles open a clear path for plug-in hybrid vehicles development

EV/HEV market forecasts

EV sales worldwide forecasts

Evolution of the different types of electrified vehicles

- **From 2010 to 2015 Electrified Vehicles will remain with modest growth except for Stop-Start Vehicles:**
  - Stop-Starts already enter most of generalist carmaker fleet. In next years, we expect SSVs to take a huge part of the overall car market
  - Stop-Starts are easy to implement and correspond to the lower amount of $ that a carmaker has to pay to reduce 1% of CO2 emission

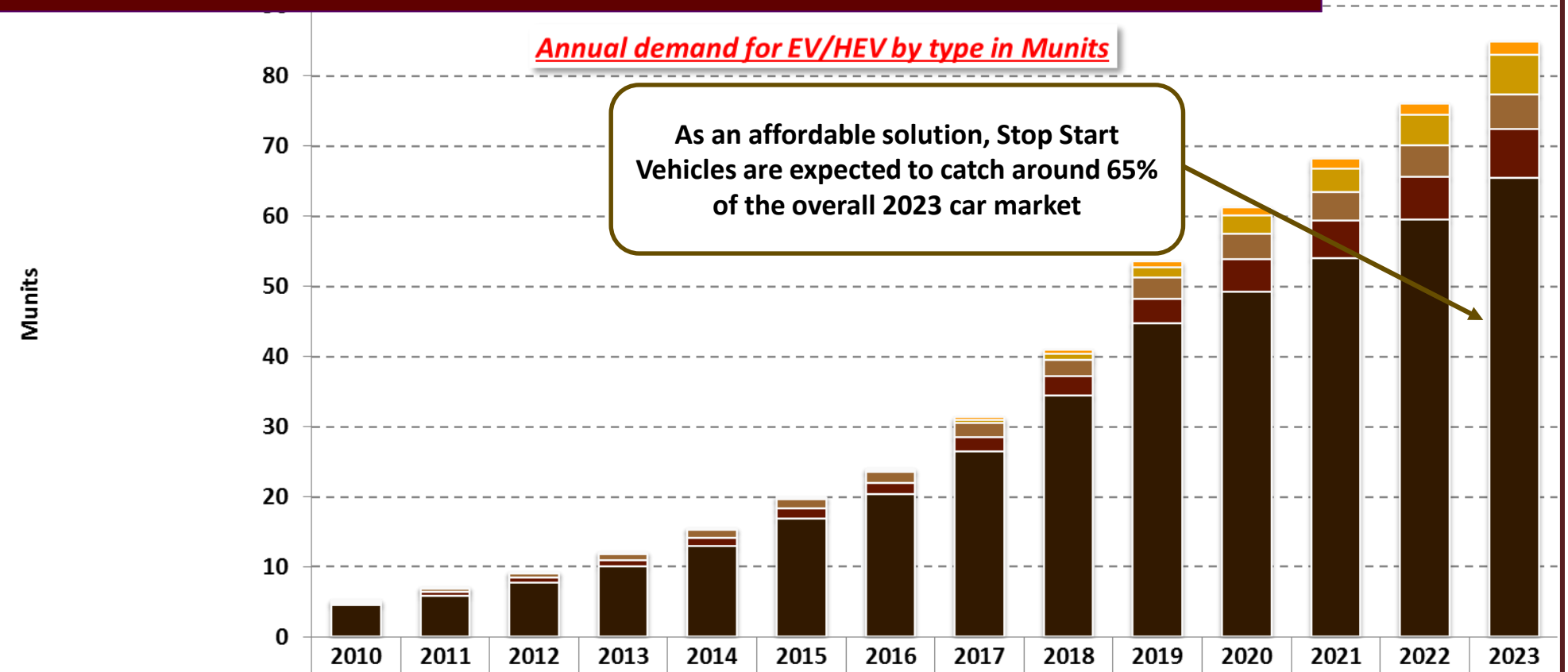
- **After 2015, 48V mild hybrid and plug In Hybrid will catch up market:**
  - Many 48V mild hybrid and PHEV project will reach SOP (Start Of Production)
  - Plug In Hybrid seems to meet every needed requirements:
    - **High level of CO2 Reduction for carmakers**
    - **Money saving from modest oil needs for consumers**
    - **Any lack of autonomy for consumers**

- **Full Cell Vehicles remain at a R&D level from now and will need a specific H2 infrastructure**
  - We do not expect FCV to enter the market for mass production before 2023

EV/HEV market forecasts

EV sales worldwide forecasts

Split by type of vehicles



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
BEV	0,02	0,04	0,06	0,11	0,14	0,19	0,24	0,36	0,54	0,82	1,22	1,41	1,62	1,86
Plug in HEV (PHEV)	-	0,01	0,05	0,09	0,14	0,20	0,30	0,52	0,88	1,49	2,54	3,30	4,29	5,57
Full HEV	0,30	0,42	0,63	0,88	1,06	1,27	1,52	1,90	2,38	2,97	3,71	4,08	4,49	4,94
Mild HEV	0,32	0,47	0,72	0,94	1,13	1,35	1,62	2,11	2,75	3,57	4,64	5,34	6,14	7,06
Stop Start Vehicles (SSVs)	4,57	5,93	7,72	10,03	13,04	16,95	20,34	26,44	34,38	44,69	49,16	54,07	59,48	65,43

Supply chain description

Supply Chain description

HEV/EV Industrial supply-chain and typical market prices from module to power train

Si devices
Toyota (JP)
Mitsubishi (JP)
Infineon (DE)
ST (FR)
Fuji (JP)
Toshiba (JP)
Hitachi (JP)

Power module Manufacturers
Toyota (JP)
Mitsubishi (JP)
Infineon (DE)
Semikron (DE)
Danfoss (DE)
Delphi (US)
Denso (JP)
BYD (CN)
Fuji Electric (JP)
Hitachi (JP)

Tier one suppliers
Europe: Valeo (FR), Continental (DE), Bosch (DE) Siemens (DE)

USA: Delphi

Asia: Toyota (JP) Hitachi (JP) Denso (JP) Mitsubishi Electric (JP) BYD (CN)

Car Manufacturers
Europe: PSA, BMW, Daimler Chrysler, Volvo, Renault

USA: Ford, GM, Tesla motors

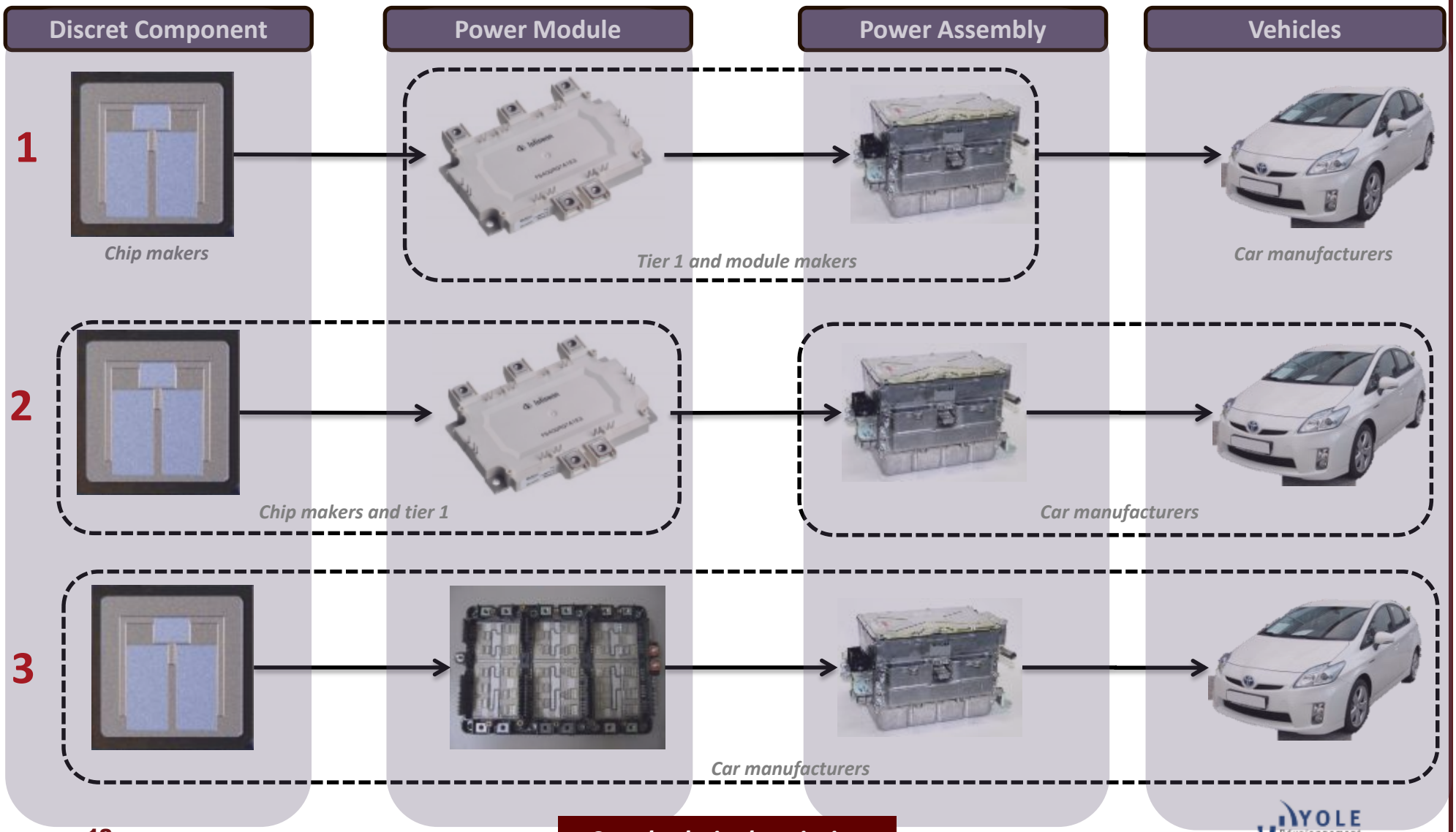
Japan: Toyota, Honda, Nissan

China: BYD, Chery, Geely

Supply Chain description

Business Models trends

Evolution of business models: 3 major remaining business models



Supply Chain description

Business Models trends

Trend is to vertically integrate the power electronics competence at car manufacturers

- **Despite a relative low market share today, the "Hyundai" business model 2 seems to more and more attract other manufacturers such as Renault or Nissan, who are developing internal competencies to make their own inverters, using external sources of semiconductor chips and power modules from the same supplier.**

- **These manufacturers will probably not manufacture their own chips and power modules and will prefer buying off-the-shelf, but will get very involved in inverter design and packaging.**

- **The main driver for such a move is the creation of a strong differentiation factor from the competition. If using the same inverter, every car maker would have almost the same performance. Making their own inverters will allow promoting different value-propositions for each of them.**

- **Power modules manufacturer landscape will change: they are working on inverters that could be sold to car manufacturers that are not involved in inverter manufacturing.**

- **Toyota will most likely keep on its business model of a fully-integrated value chain.**

TECHNOLOGY TRENDS

Vehicle Architectures

Power electronics used in electrified vehicles

Key elements for power assembly evolution

$/kW

kW/kg

kW/l

Technical Breakthrough

Power Assembly Architecture

- **Converter Topologies (mainly for LV-HV DC/DC and AC/DC)**
- **Inverter has to be developed according to the electric motor**

Passive Elements (Cooling, capacitors, busbars, etc…)

- **High Temperature Capacitors, Laminated Busbars**
- **Enhanced cooling of the power converter**

Power Packaging

- **Low stray inductance packaging**
- **High Temperature and reliable assemblies**

Wide Band gap Semiconductors

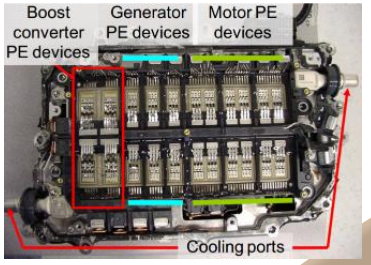
- **High Temperature operation**
- **More compact inverters**

Power assembly

Competitive assembly technology

Roadmap of Power assembly technology toward higher integration and power density

- **Improved cooling**
- **Higher power density**
- **Mechatronic improvement**



Power assembly technologies

Direct Cooling

Double side cooling

Co-integration motor + inverter:
- **Increase power density**
- **Inverter mechatronic design to fit with motor aspect ration**

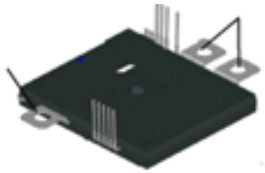
Converters co-intergration
- **DC/DC Boost + Inverter + Generator**
- **Inverter + LV-HV DC/DC**
- **On board DC/DC + LV-HV DC/DC**

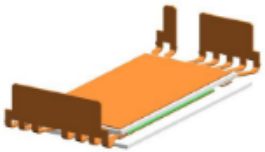
Power module packaging

Competitive packaging technology

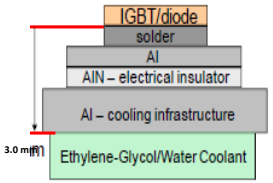
Roadmap of Power module technology toward higher integration and power density

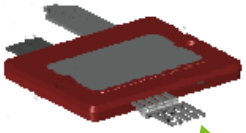
- **Improved cooling**
- **Higher integration**
- **High freq. compatible**





2010 Prius





Power module packaging technologies

Denso 2008/Lexus LS
- Single IGBT/diode packaging
- Flip-chip soldering
- Double side cooling
- Too expensive

Toyota 2010
- Standard packaging
- Ribbon bonding
- Direct substrate cooling

Honda 2010
- Epoxy packaging
- Cu lead bonding
- Direct substrate cooling

Delphi 2010
- Single IGBT/diode packaging
- Flip-chip soldering
- Direct substrate cooling

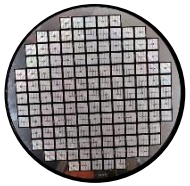
Bosch 2013
- Molded package
- Die on Leadframe
- Thick Copper layer for thermal spreading
- Direct substrate cooling

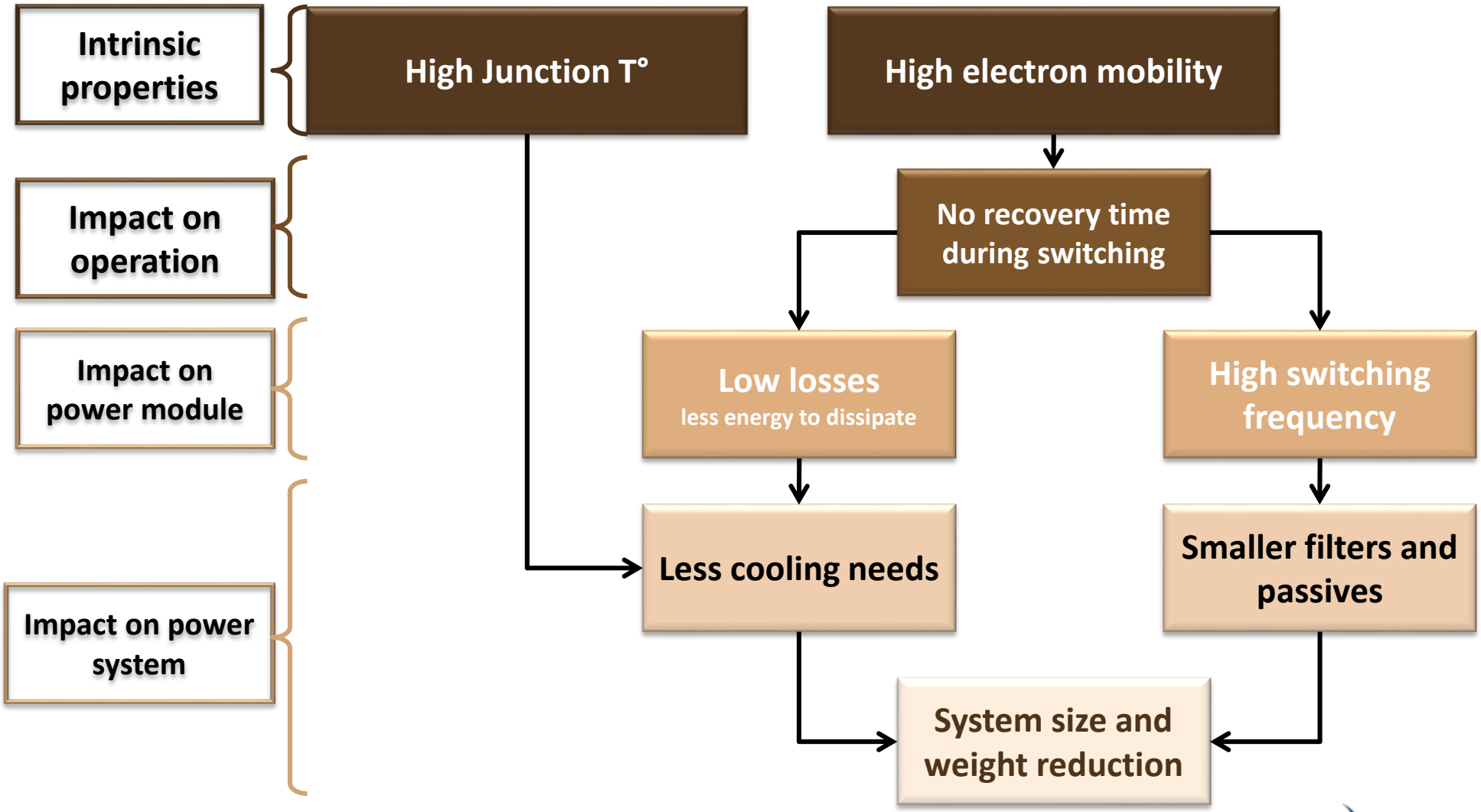
Mitsubishi 2014
- Six Pack IGBT/Diode Package
- Cooling fin
- Thick Copper layer for thermal spreading
- Direct substrate cooling

Semiconductor innovation

Wide band-gap semiconductors: SiC and GaN

Reasons for WBG Added Value

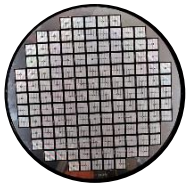




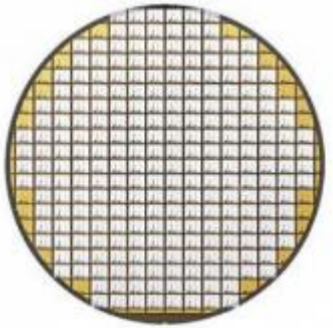
Semiconductor innovation

Wide band-gap semiconductors: SiC and GaN

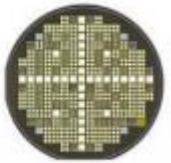
Case Study: Toyota



- **Toyota exhibited the SiC technology at the 2014 Automotive Engineering Exposition, to be held from May 21 to May 23 at the Pacifico Yokohama convention center in Yokohama**
- **The demonstrator was produce with Denso**
- **Major achievements:**
  - **40% size reduction**
  - **10% improve in Fuel efficiency**



Si Wafer



SiC Wafer

Boost + Inverter + Generator With Si device

Boost + Inverter + Generator With SiC device

Conclusion

Conclusion

Market

- **As a conclusion to this 2014 report, the EV and HEV market will definitely grow in the next ten year. Even if market is mainly pulled at first by highly restrictive regulation, the whole supply chain has developed technical solutions to overcome EV/HEV adoption breaks:**
  - Vehicle/Battery Cost
  - Vehicle autonomy
  - Ability to recharge easily

- **In 2023, 18%+ of Vehicle sold will be mild HEV, HEV, PHEV or BEV thanks to a large adoption of PHEV and 48V mild HEV vehicles. We expect China to become the bigger market for electrified vehicle by 2018**

- **With such a market volume, power converters will reach 16B$+ and impact the whole power electronic market. New development from supplier (Tier 1, Tier 2, etc..) will fit automotive drivers and specifications**
  - Power Density
  - Reliability
  - Cost

Conclusion

Supply Chain

- **Car maker know-how has been built on combustion engines: transition to electric engines must go with transition of this specific know-how. Electric conversion in automotive application can now be addressed by many players. All over the supply chain, landscape is moving fast**
  - Historical suppliers want to keep automotive market for them
  - New entrant want to be part of these new business opportunities
  - We see many vertical integration within the supply chain to gain market shares and increase profitability

- **Also, car makers need to differentiate compare to the competition by being intrusive (at hardware and software level) in motor or converters development. Some of them are producing their own inverter (and even their own power module) to reduce supplier margin**

- **All these business models will coexist in the next years and then consolidate with the market ramp up (around 2018)**

Conclusion

Technology

- **Large R&D expenses for innovation have been invested to enter this promising market with tough competition zone. EV/HEV is now facing huge technical breakthrough in many fields**

- **The whole power conversion architecture will drastically be impacted in the next ten years. Needs in power density will lead to improvement in thermal management, passive elements volumes and mechatronics. Power modules will fit with automotive drivers (cost, reliability) and lead innovation for all power electronic applications.**

- **Wide Band Gap semiconductor will reach electrified vehicle market with:**
  - **Opportunities on vehicle architecture:**
    - **Using hot water cooling system from ICE to cool power converters (for HEV and PHEV)**
    - **Using Air cooling for electric motor and power converters (for BEV)**
  - **Power converter volume may be shrunk by 40% to help mechanical integration**
  - **Losses reduction will allow better fuel efficiency and autonomy**

- **Fuel Cell Vehicles penetration rate will clearly depends on its cost and H_2 charging infrastructure**