

Power Devices Business Briefing

**— Providing crucial energy-saving devices
as a global top-level power devices manufacturer —**

Nov. 22, 2017

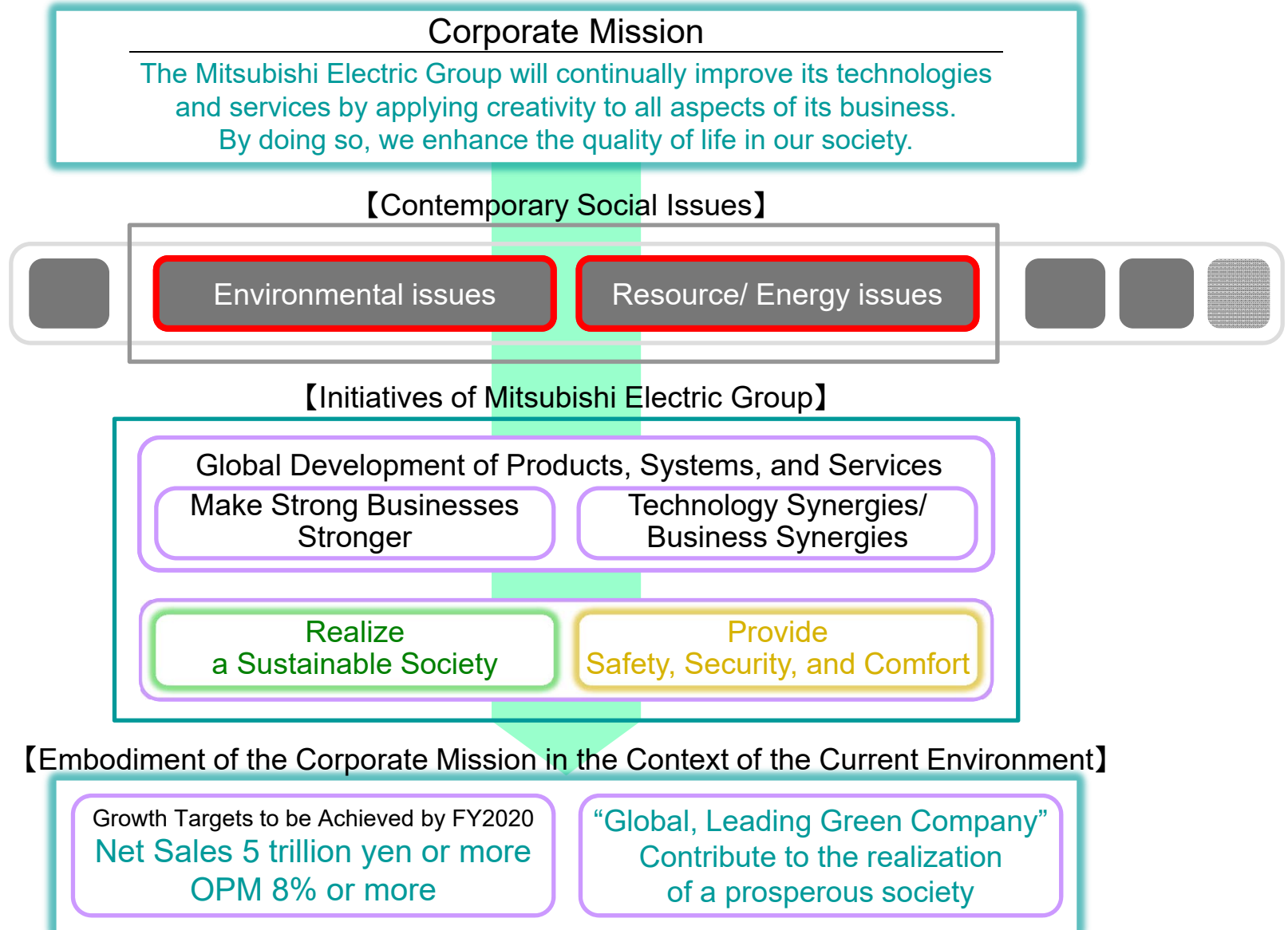
Toru Sanada
Executive Officer
In charge of Semiconductor & Device

Contents

1. Introduction
2. Positioning and Features of Business
3. Business Environment
4. Growth Targets
5. Differentiation Strategy
6. Business Strategy by Segment
7. Manufacturing Strategy
8. Summary

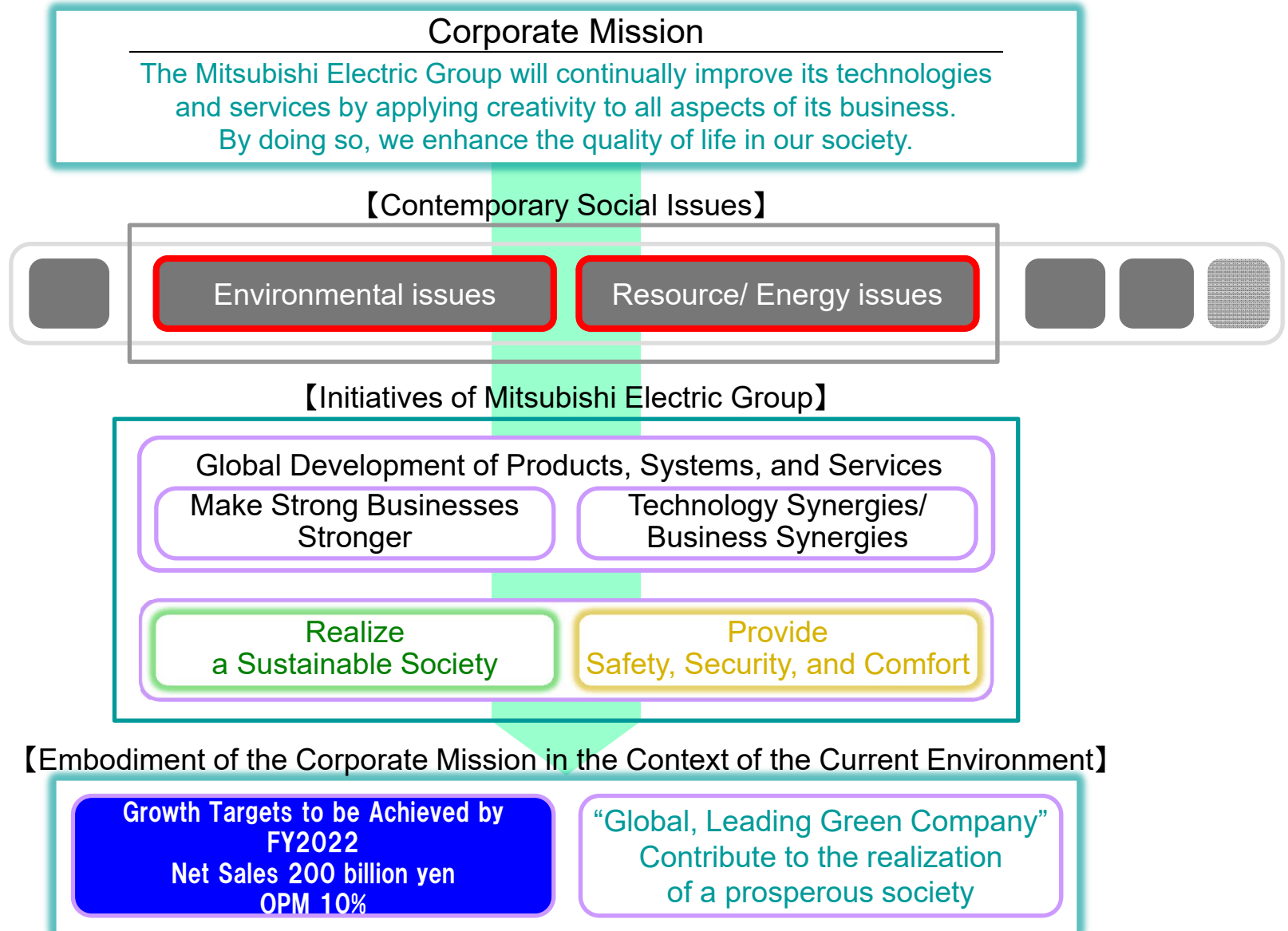
1. Introduction

Embodiment of the Corporate Mission



1. Introduction

Embodiment of the Power device Business Mission

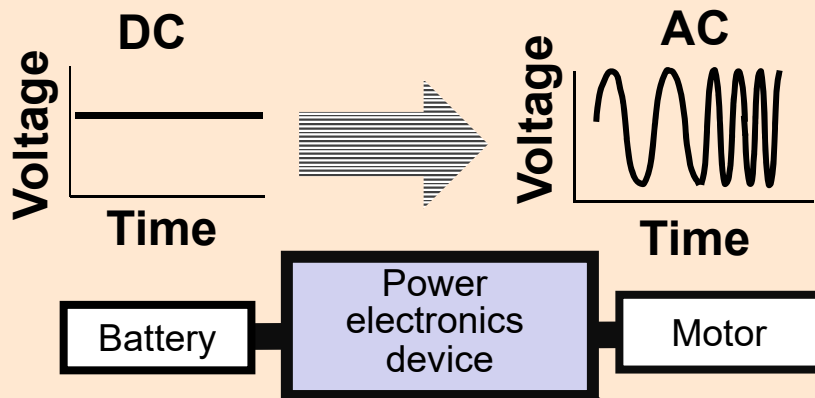


2. Positioning and Features of Business

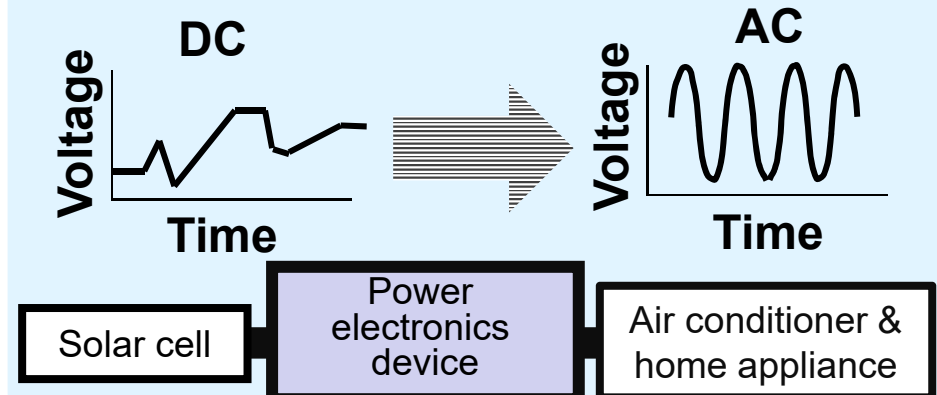
Power devices are crucial for low-carbon societies

- Semiconductor devices that efficiently control electric power by converting electricity from DC to AC, DC to AC, or by raising or lowering voltage
- Key energy saving devices used in a wide range of sectors including power control for industrial machinery, traction, electric vehicles (EV*), home appliances, photovoltaic power generation, wind power generation, motor control, and more.

Motor driving inverter



Photovoltaic power generation power conditioner



Power Devices

* EV: Electric Vehicle

2. Positioning and Features of Business

Positioned as a business to drive corporate growth

Energy & Electric Systems

- **Power Systems**
Power generation systems,
Transmission & distribution systems,
Power distribution systems,
Particle therapy systems, etc.
- **Transportation Systems**
Inverters, main motors and
air conditioning systems for railcars,
Train Vision, Train control and
management systems,
Railcar operation management systems,
Signaling systems, etc.
- **Building Systems**
Elevators, Escalators,
Building management systems, etc.
- **Public Systems**
Water treatment systems,
Disaster prevention systems, etc.



**Growth
Drivers**

Industrial Automation Systems

- **Factory Automation (FA) Systems**
PLCs, AC servomotors,
CNCs, Industrial robots,
Laser processing machines, etc.
- **Automotive Equipment**
Starters, Alternators, Car multimedia,
EPS system products,
Electric powertrain system, etc.



Information & Communication Systems

- **Space Systems**
Satellites, Ground systems for
satellite control, etc.
- **Defense Systems**
Radar equipment, Antennas, etc.
- **Communication Systems**
Optical, wireless and satellite
communications systems, etc.
- **Video Monitoring Systems**
Network camera systems
- **IT Solution**

Electronic Devices

- **Power Devices**
SiC¹ modules, IGBT² modules, etc.
- **High Frequency and Optical Devices**
High frequency devices (GaN³
and GaAs⁴), Optical devices, etc.
- **TFT⁵ LCD Modules**

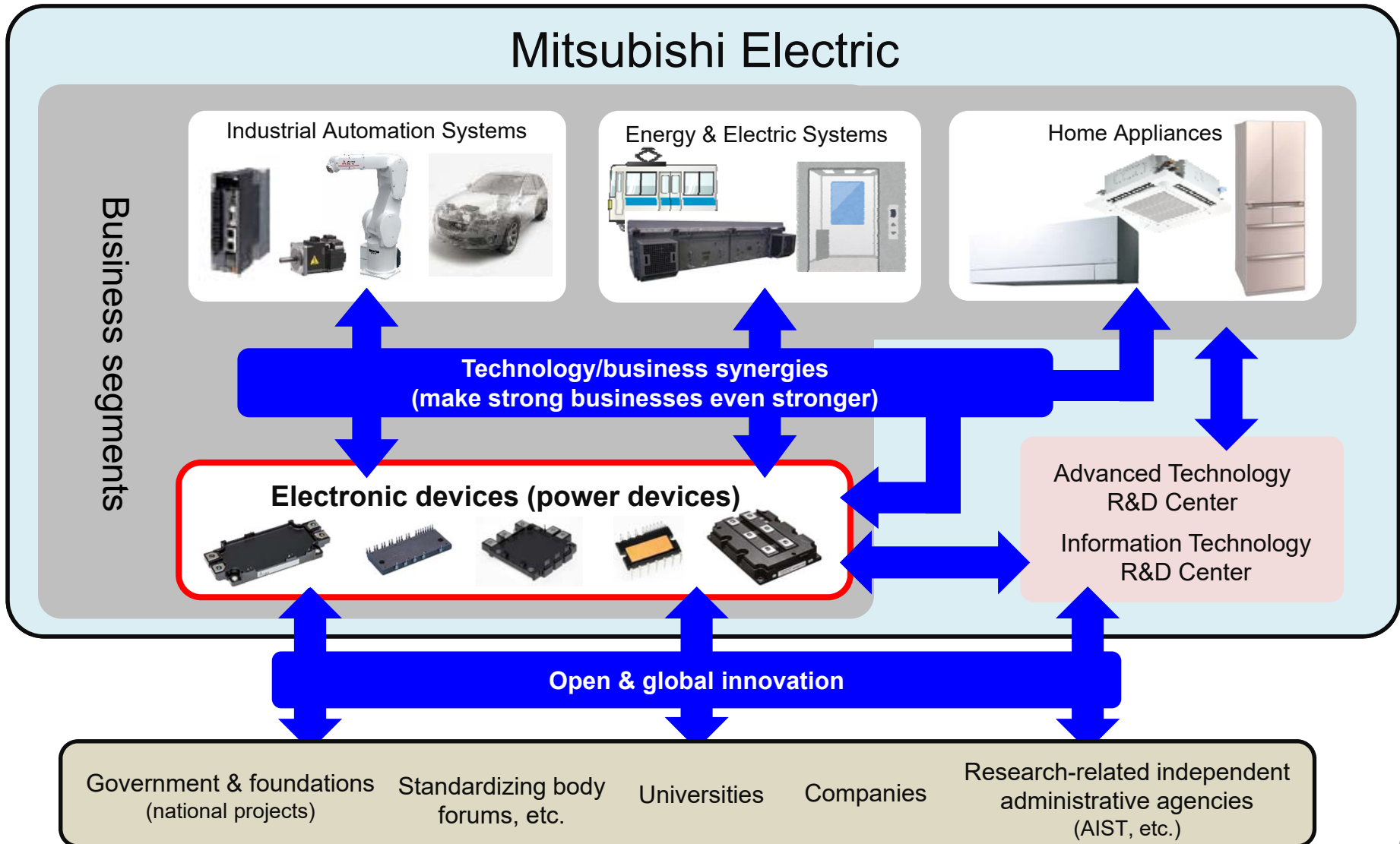
Home Appliances

- **Air-Conditioning & Refrigeration Systems**
Room and package air conditioners,
Multiple AC units for buildings, Lossnay
ventilation systems, Chillers, etc.
- **Housing Equipment**
Smart appliances, Lighting, HEMS, etc.
- **Kitchen and Other Household Appliances**

1 SiC: Silicon carbide 2 IGBT: Insulated gate bipolar transistor 3 GaN: Gallium nitride
4 GaAs: Gallium arsenide 5 TFT: Thin film transistor

2. Positioning and Features of Business

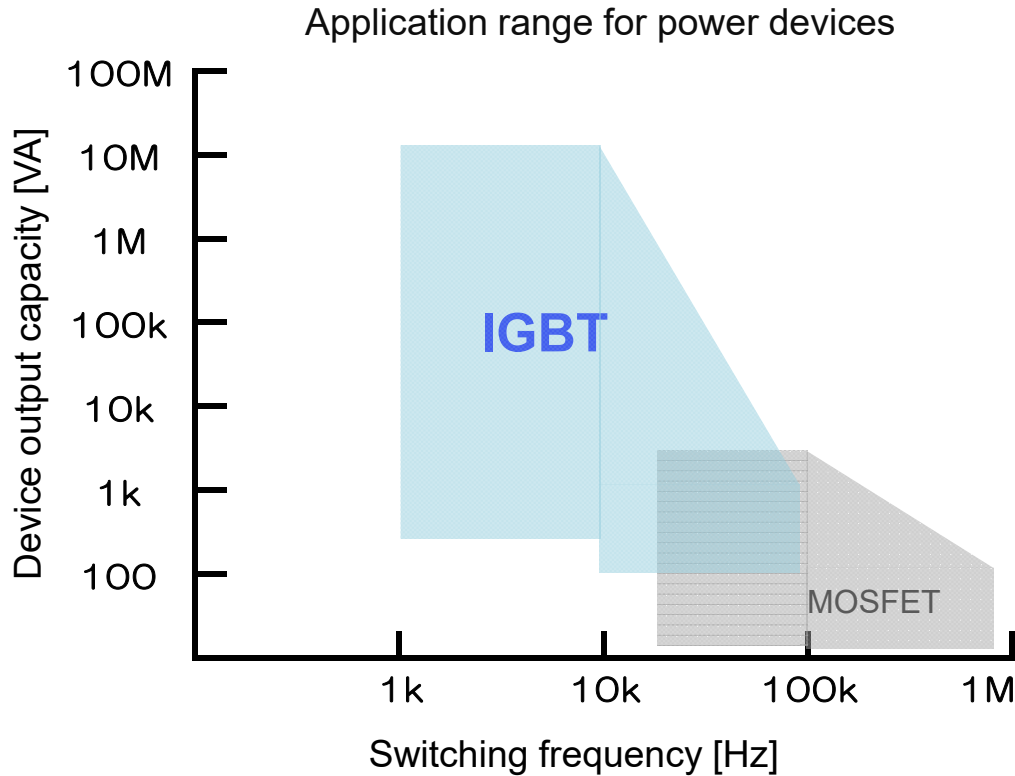
Strengths are in-house business and technology synergies, and global innovation



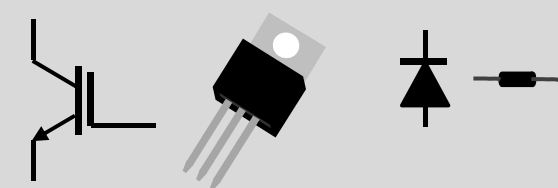
2. Positioning and Features of Business

Our Focus : IGBTs and Modules

IGBT and MOSFET*

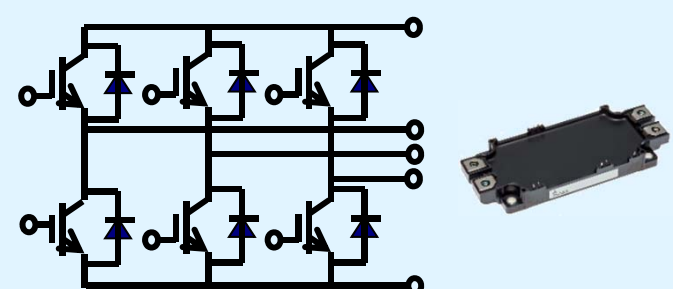


Discrete



IGBT **Diode**

IGBT module

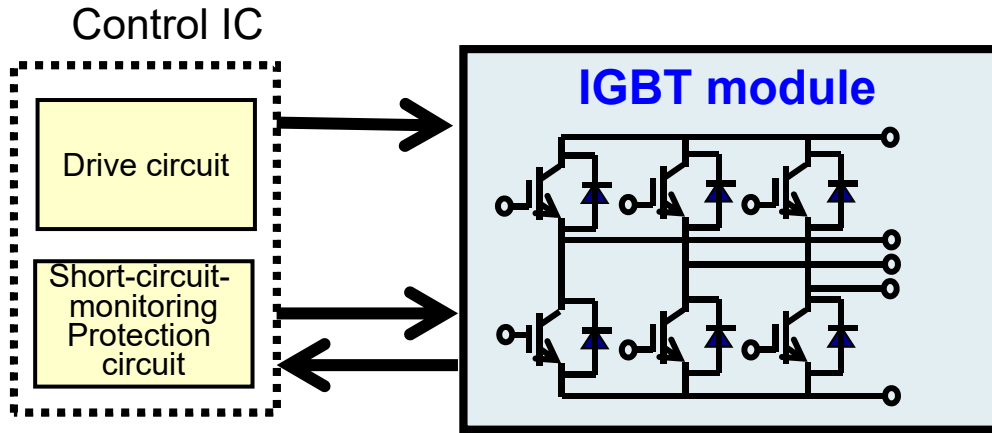


Compound power devices with multiple IGBTs and diodes in a single package

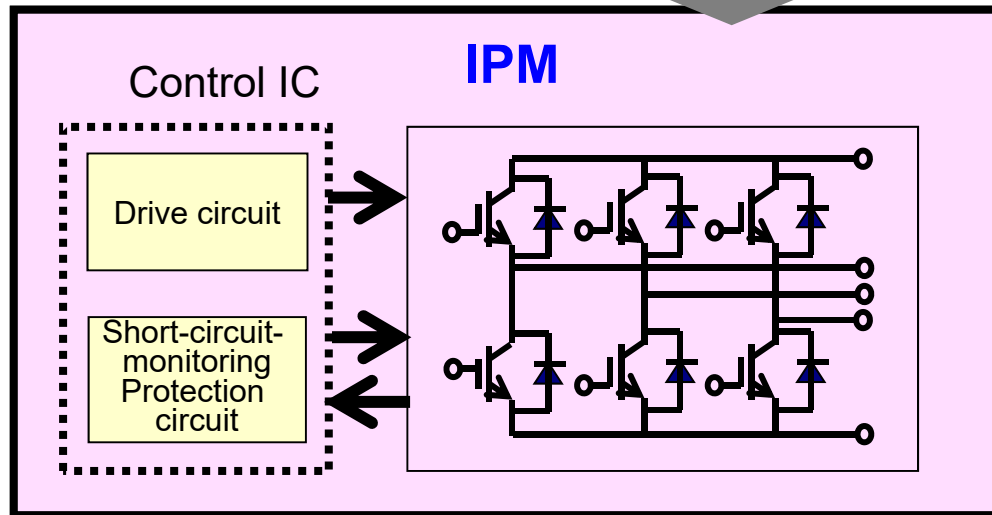
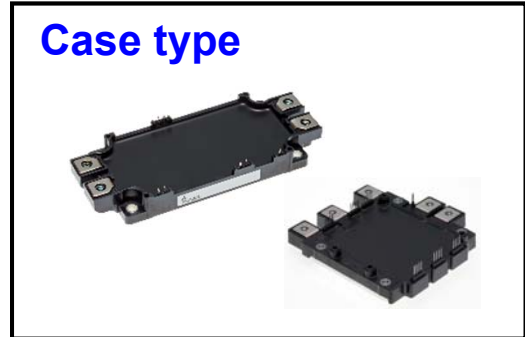
* MOSFET : Metal oxide semiconductor field effect transistor

2. Positioning and Features of Business

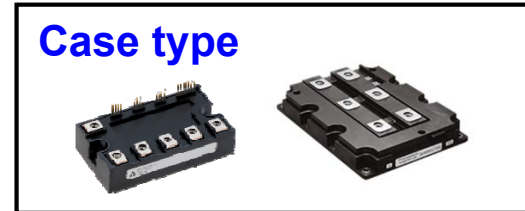
Focus on maintaining world's top share¹ in IPM²



Package

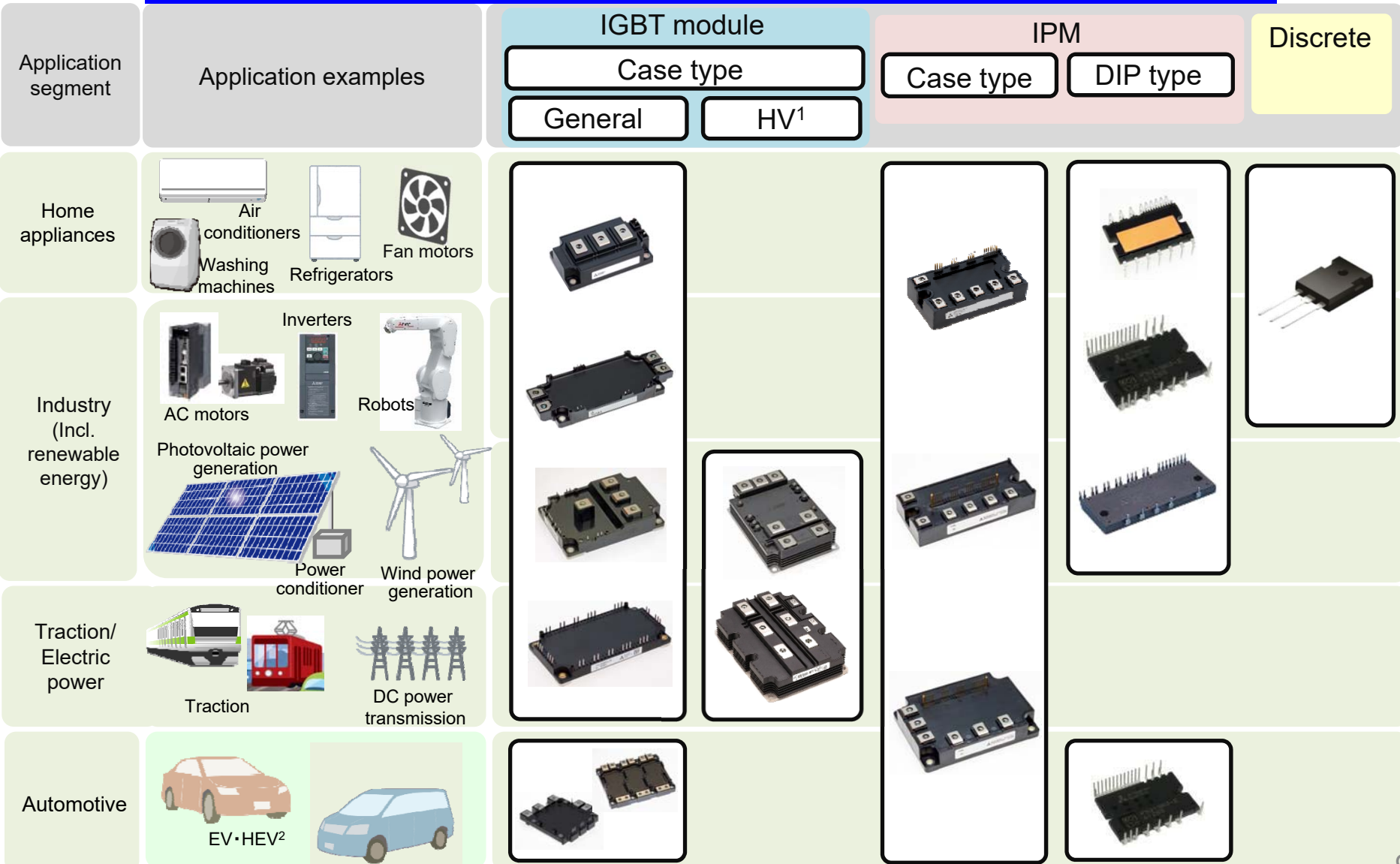


Package



2. Positioning and Features of Business

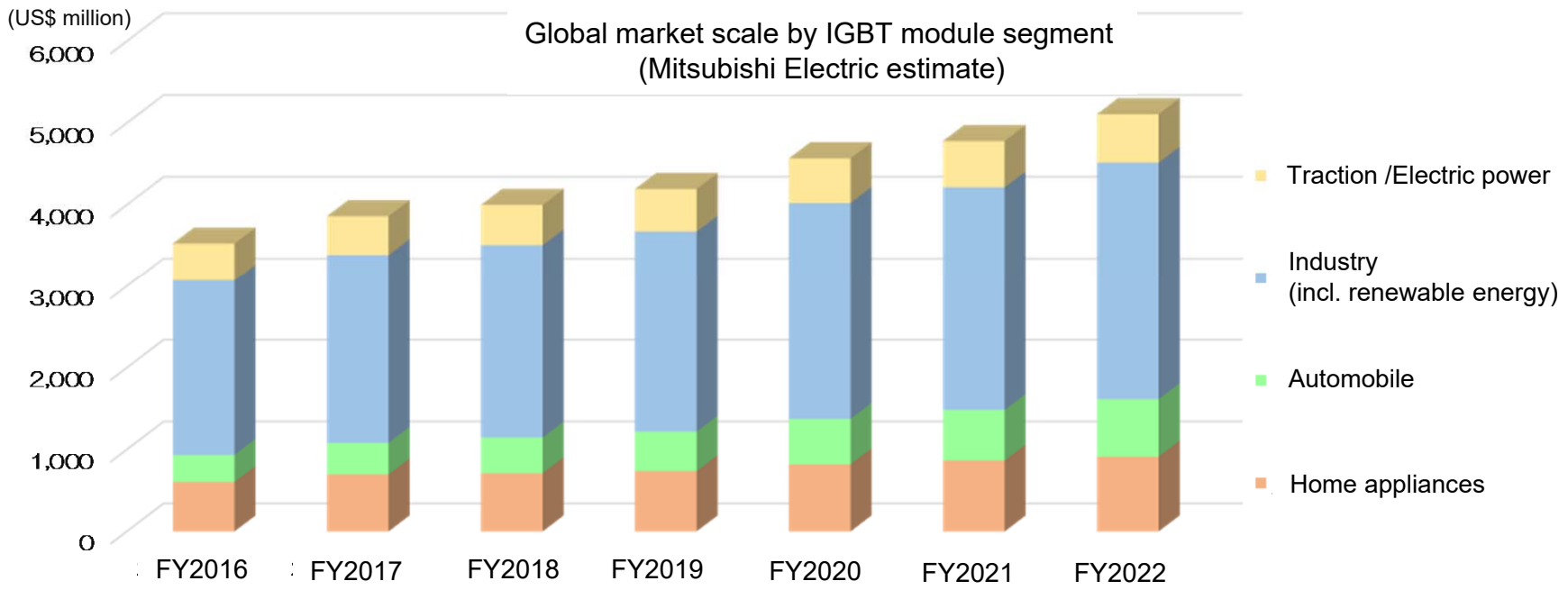
Focused on Four Segments : Meeting Diverse Needs



1 HV: High voltage 2 HEV: Hybrid electric vehicle

3. Business Environment

Annual market growth rate of about 6%

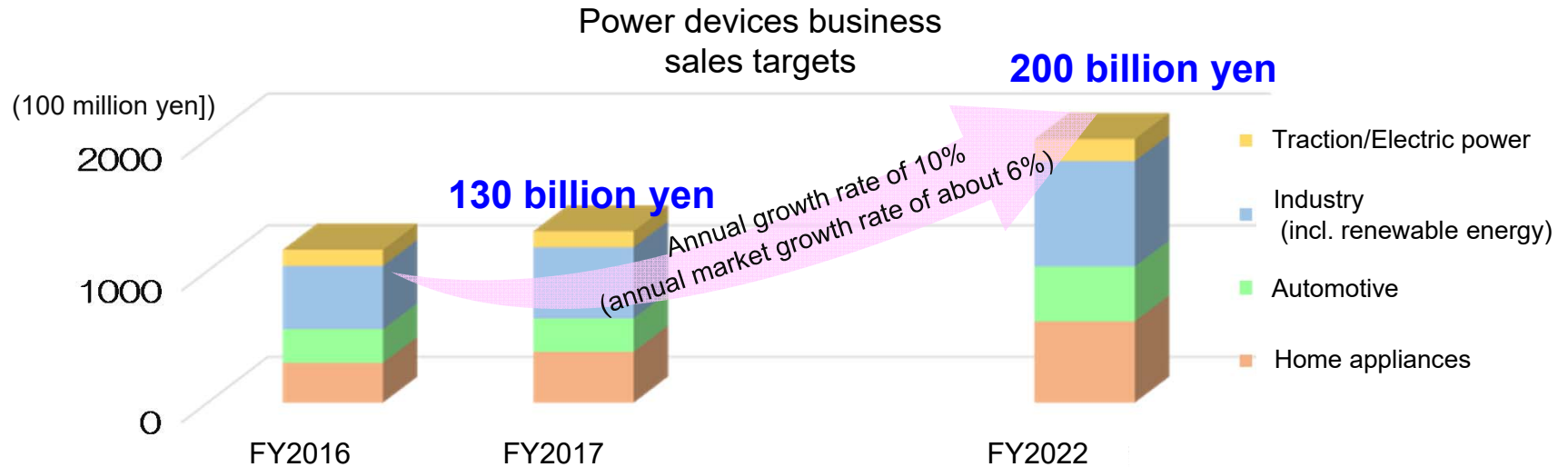


Background of power devices market expansion

- Home appliances:** Growth due to expansion of market for major appliances (air conditioners, refrigerators, washing machines, etc.) and progress in shift to inverters
- Automotive:** High growth due to accelerated shift to EVs due to more stringent environmental regulations
- Industry:** (incl. renewable energy) Expansion, mainly in FA market, due to investment in factory automation, power efficiency improvements, and strengthened environmental regulations for motors (incl. renewable energy). Growth will accompany expansion of renewable energy (solar and wind) markets around the world.
- Traction/Electric power :** Moderate growth in electric railway rolling stock market in line with population growth, urbanization, etc.

4. Growth Targets

FY2022: Net sales of 200 billion yen and OPM of 10%

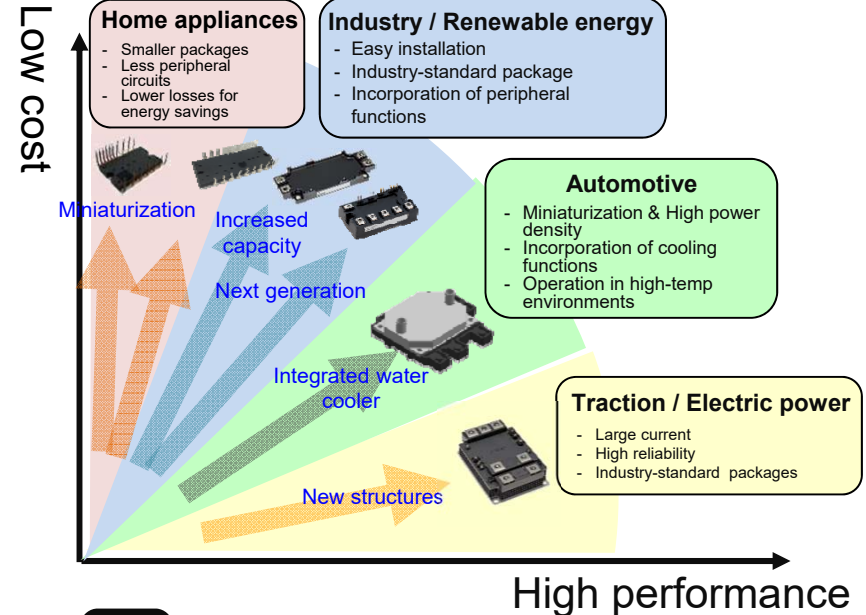
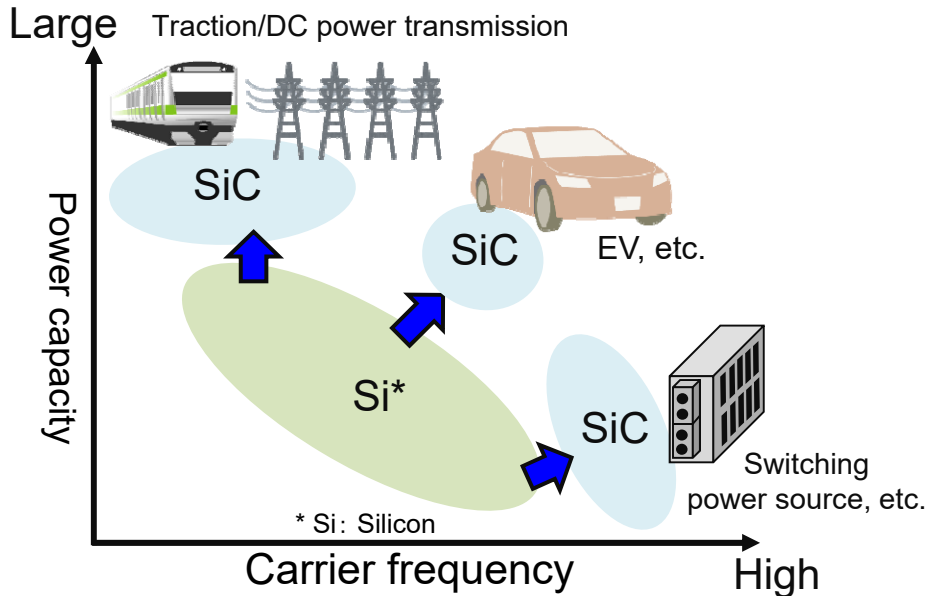


Growth strategy : 10% growth in focus segments (exceed market growth of 6%)

- Home appliances: Enhance product lineup balanced with market demands (higher functionality, lower power loss, and lower costs), aiming to become the undisputed market leader
- Automotive: Capture opportunities in the shift to electric-power automobiles and grow strongly worldwide
- Industry: (incl. renewable energy) Introduce competitive products to increase share in major markets for power device business
- Traction/Electric power : Pursue greater added value in infrastructure segment where growth is not high but demands for quality and reliability are high, to maintain the position as a top supplier

5. Differentiation Strategy

Developing high-efficiency power devices (chip)s and packages that match market needs are inseparable for differentiation



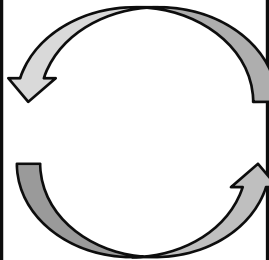
Si: Balance performance and cost

- Low power loss
- Wide application range
- High reliability

SiC: High performance for value-added applications

- Lower power loss (70% less than Si)
- High-frequency switching (100kHz class)
- High temp. operation (200 °C class)

Chip development



Package development

Miniaturization

- High-current-density packages
- High-heat-dissipation substrates

Longer life

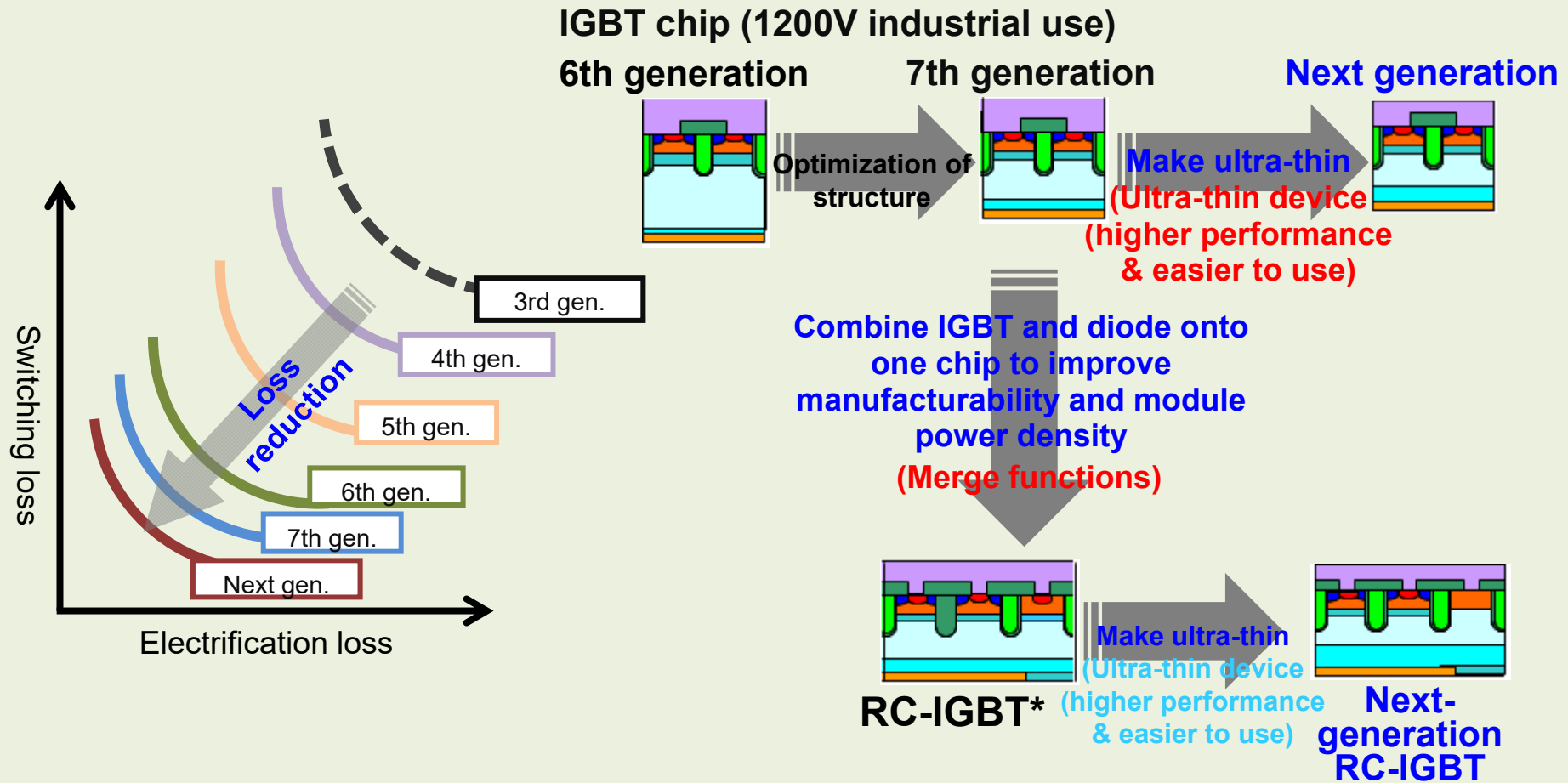
- Low-stress structure at heat cycle
- Low-thermal-resistance materials (bonding materials & encapsulants)

Higher functionality

- Integrated radiators
- Incorporation of peripheral circuits

5. Differentiation Strategy: Si IGBT chips

Evolution of Si IGBT chips



* RC-IGBT: Reverse conducting-IGBT

5. Differentiation Strategy: SiC

Become No.1 in many SiC applications¹

- Pursue advanced achievements through synergy among strong power electronics business units within company
- Introduce SiC power modules from the start, applying SiC to product groups for all applications

Equipped for first time in the world



Traction



Commercialized SiC inverter for use in railcars (October 2011)



Installs Railcar Traction System with All-SiC Power Modules on Shinkansen Bullet Trains (Announced in June 2015)

Equipped for first time in the world



Industry



Equipped for first time in the world

Launched Computer numerical control (CNC) drive unit equipped with SiC power module (Released in December 2012)



Equipped for first time in the world

Under Development

Develops SiC for application in elevator control systems (Announced in February 2013)



Automotive



World smallest

Under Development

Develops world's smallest SiC Inverter for HEVs (Announced in March 2017)



Energy



Verified highest power conversion efficiency for photovoltaic power conditioner (domestic industry) (Announced in January 2011)



Launched power conditioner for photovoltaic equipped with full SiC-IPM (Released in January 2015)

Industry best



Home Appliances



Equipped for first time in the world

Launched "Kirigamine" inverter air conditioner (Released in October 2010)



Launched package air conditioners with full SiC DIPIPM² in Japan (Released in May 2016)

Equipped for first time in industry

Development of these modules and applications has been partially supported by Japan's Ministry of Economy Trade and Industry (METI) and New Energy and Industrial Technology Development Organization (NEDO).

¹ The year and month listed are based on press releases or information released during the product launch month in Japan.

² DIPIPM: Registered trademark of Mitsubishi Electric Corporation

5. Differentiation Strategy: SiC chips

Continuous development of SiC to lower costs and improve performance

Features of SiC chips

Item	Si	SiC	Customer benefits	Combined uses
Power loss	1	1/3	High efficiency, higher output and energy savings	EVs, air conditioner, railways, and DC power transmission
High temp. operation	175°C	T _j >200°C	Reduced heat-dissipation fins	EVs and special inverters
High-speed switch	30KHz	F _c >100KHz	High efficiency and smaller size	Power sources and non-contact power supply

Advancement of SiC chips

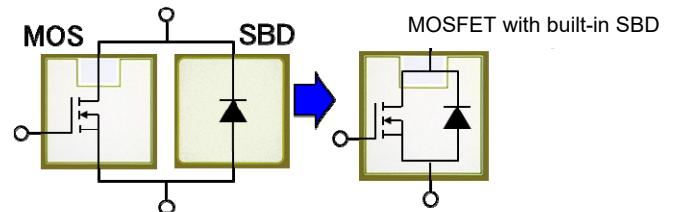
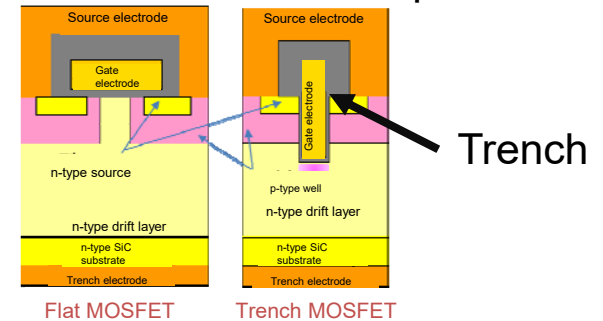
➤ **Trench MOSFET** ⇒ **Smaller size/Low loss/High reliability**

- Gate placed on wall of trench formed downward and cell density improved/refined with aim of lowest loss in the industry
- Original field alleviating structure employed to improve reliability

➤ **MOSFET with built-in SBD*** ⇒ **Smaller size/Low cost**

- Mitsubishi Electric original technology where chip is miniaturized by building SBD in to MOS Effective especially for high-voltage devices and has approx. 60% surface area for 3.3kV

MOSFET structure comparison

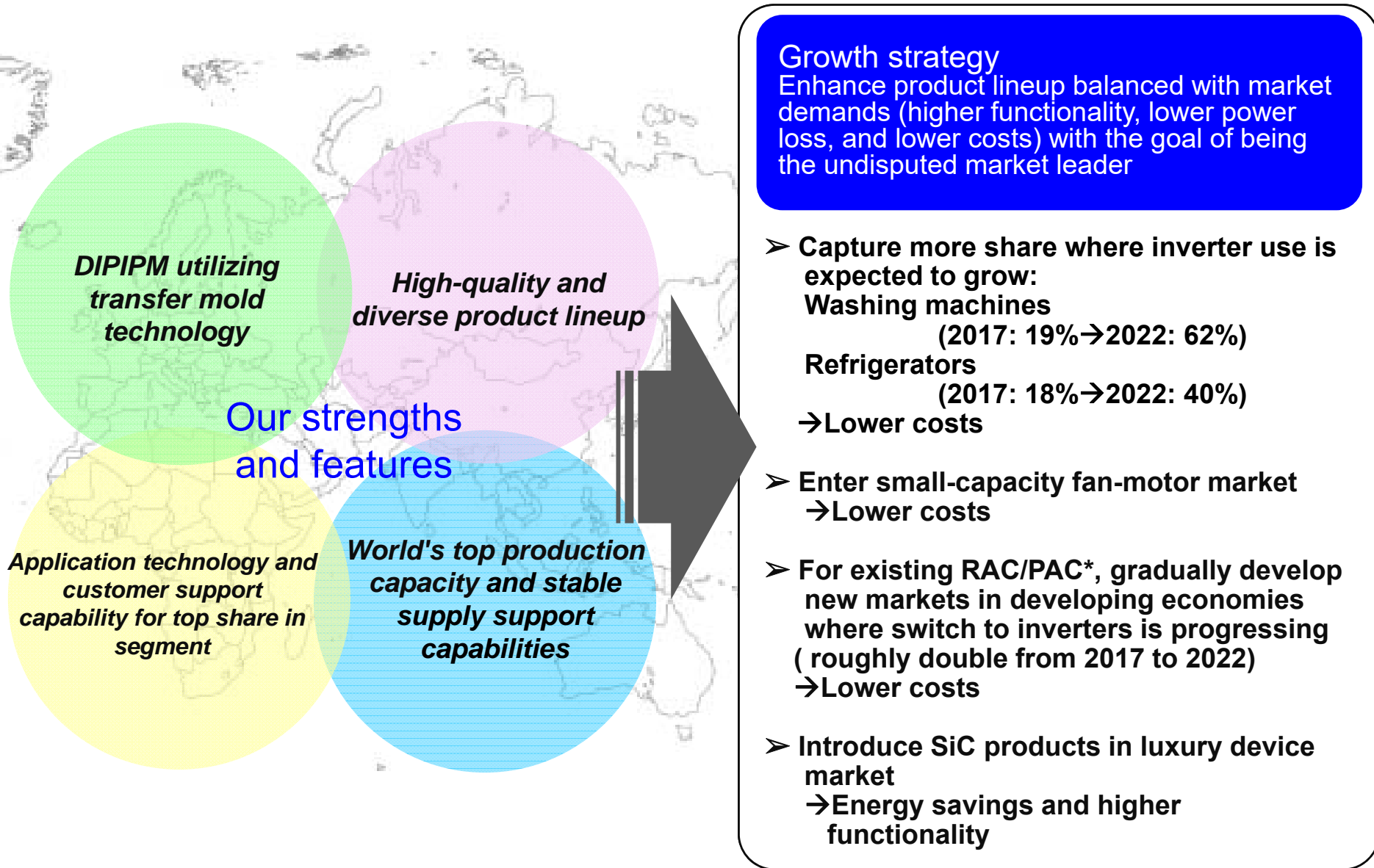


Chip surface area reduction by building in SBD (image)

Forward-looking R&D is pursuing new-material power devices, such as vertical GaN and gallium oxide, in addition to SiC-IGBT (current MOSFET)

* SBD: Schottky barrier diode

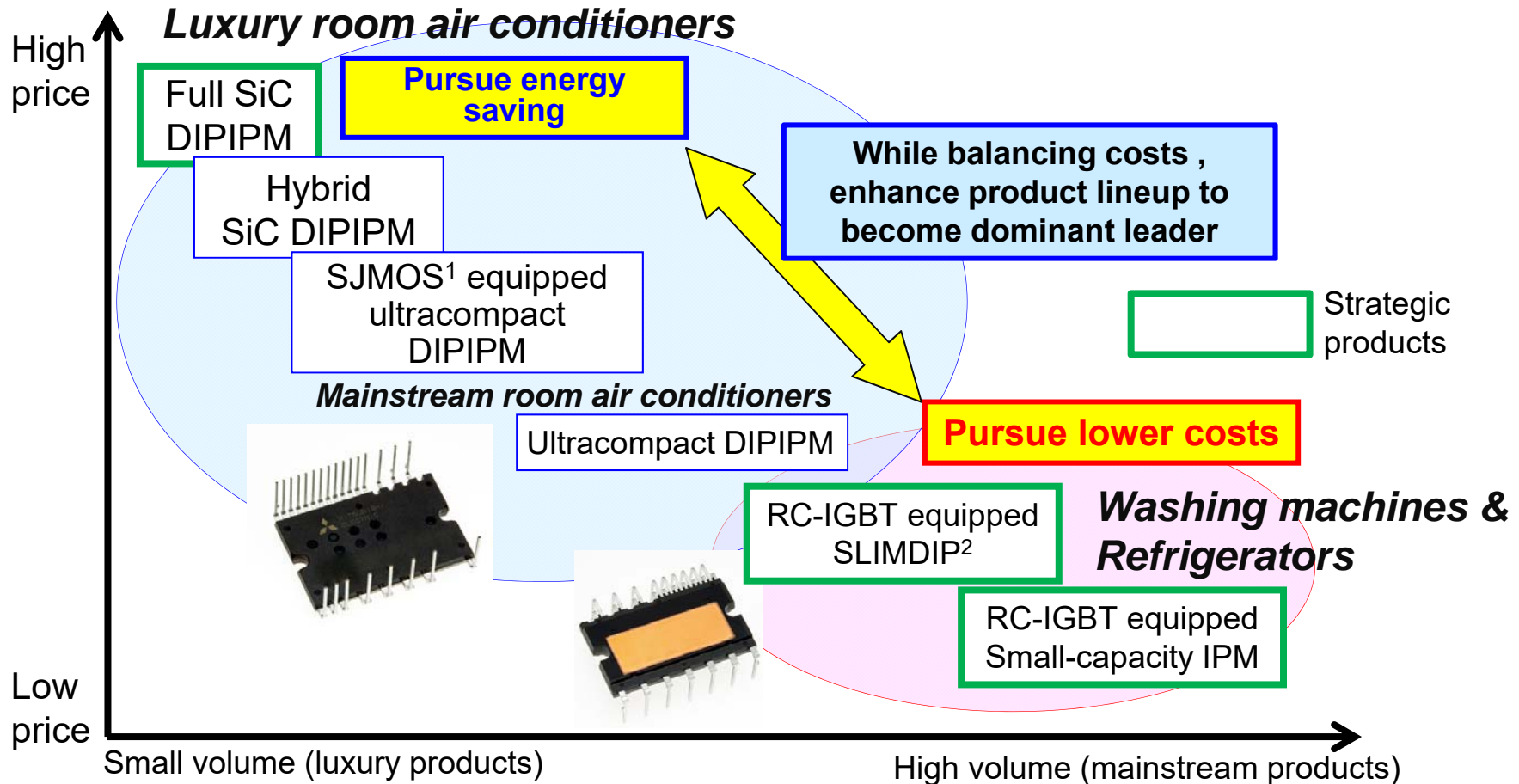
6. Business Strategy by Segment : Home appliances



6. Business Strategy by Segment: Home appliances

Product strategy

- Higher functionality: More products equipped with SiC and reduce loss
- Lower costs: Apply RC-IGBT chips and low-cost packages



1 SJMOS: Super Junction MOSFET 2 SLIMDIP: Registered trademark of Mitsubishi Electric Corporation

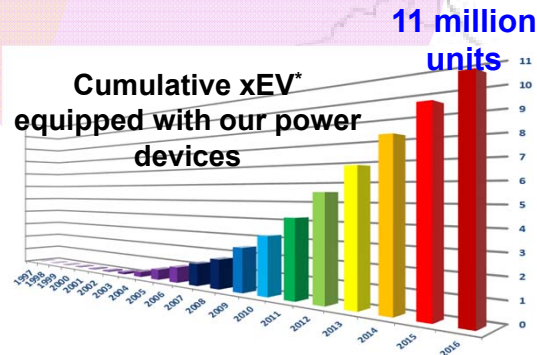
6. Business Strategy by Segment: Automotive

Ability to offer diverse solutions according to customer demands (chips & modules)

Our strengths and features

High quality, strong technical application Support, and customer-support abilities

Abundant know-how and good market performance from start of EV market



Growth strategy

Capture opportunities in shift to electric-power automobiles and grow strongly worldwide

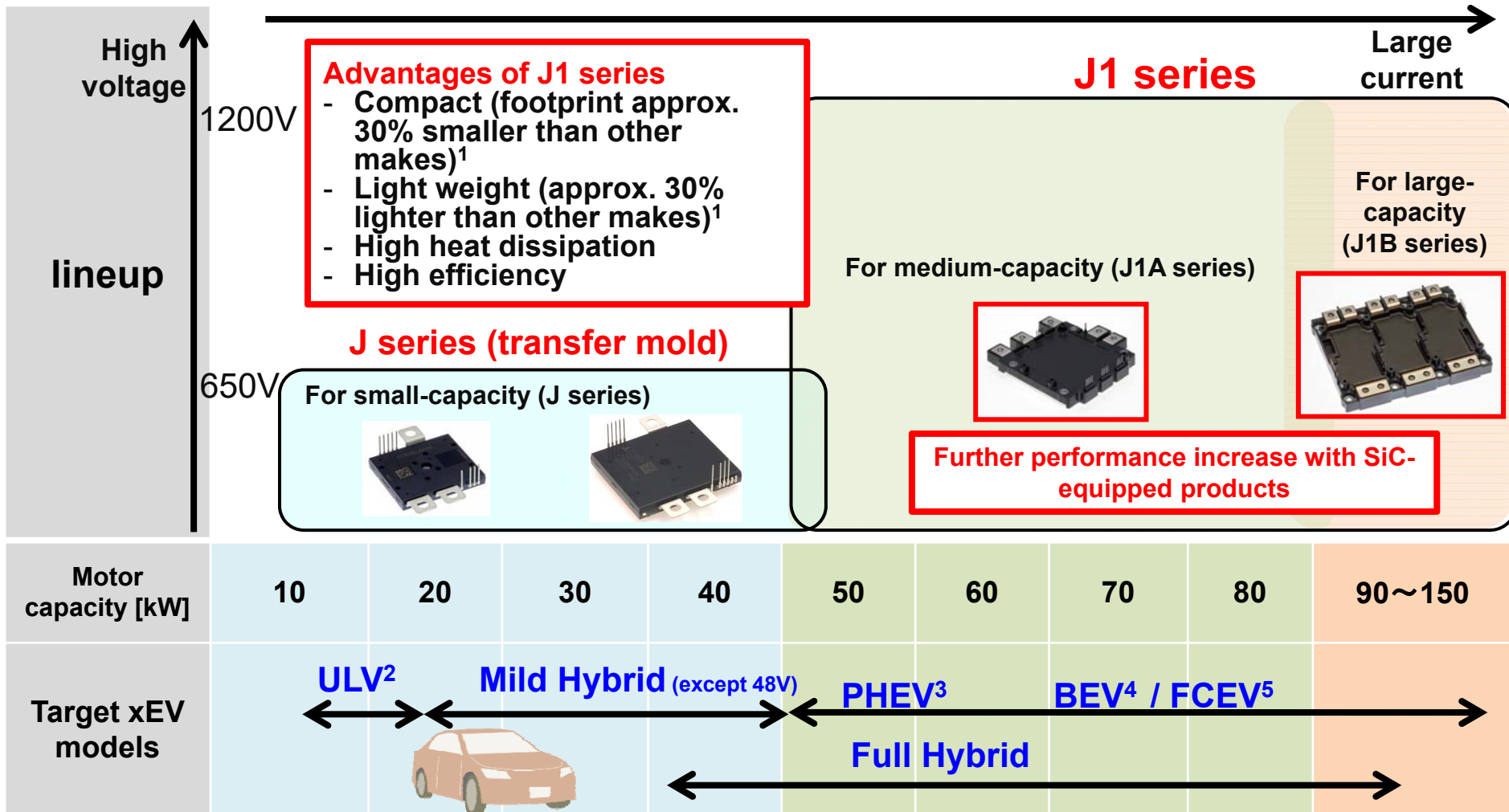
- Shift focus from Japan to overseas markets
- Shift development and delivery from customized to standardized products
- Deploy standardized modules (J/J1 series) globally
- Raise chip performance
 - Si: Raise IGBT and RC-IGBT performance
 - SiC: Shift to 6-inch and trench type

* xEV: General term for electric vehicles

6. Business Strategy by Segment: Automotive

Standard module product strategy

➤ Expand product lineup according to market demands (high voltage, large current)



6. Business Strategy by Segment: Industry, incl. Renewable Energy

*Know-how accumulated
serving Japanese users
over many decades
and market performance*

**Our strengths
and features**

*Products offering
competitive
advantages based on
7th generation chips
and new package
technologies*

*High quality, strong
technical application
support and customer
support abilities*

Growth strategy

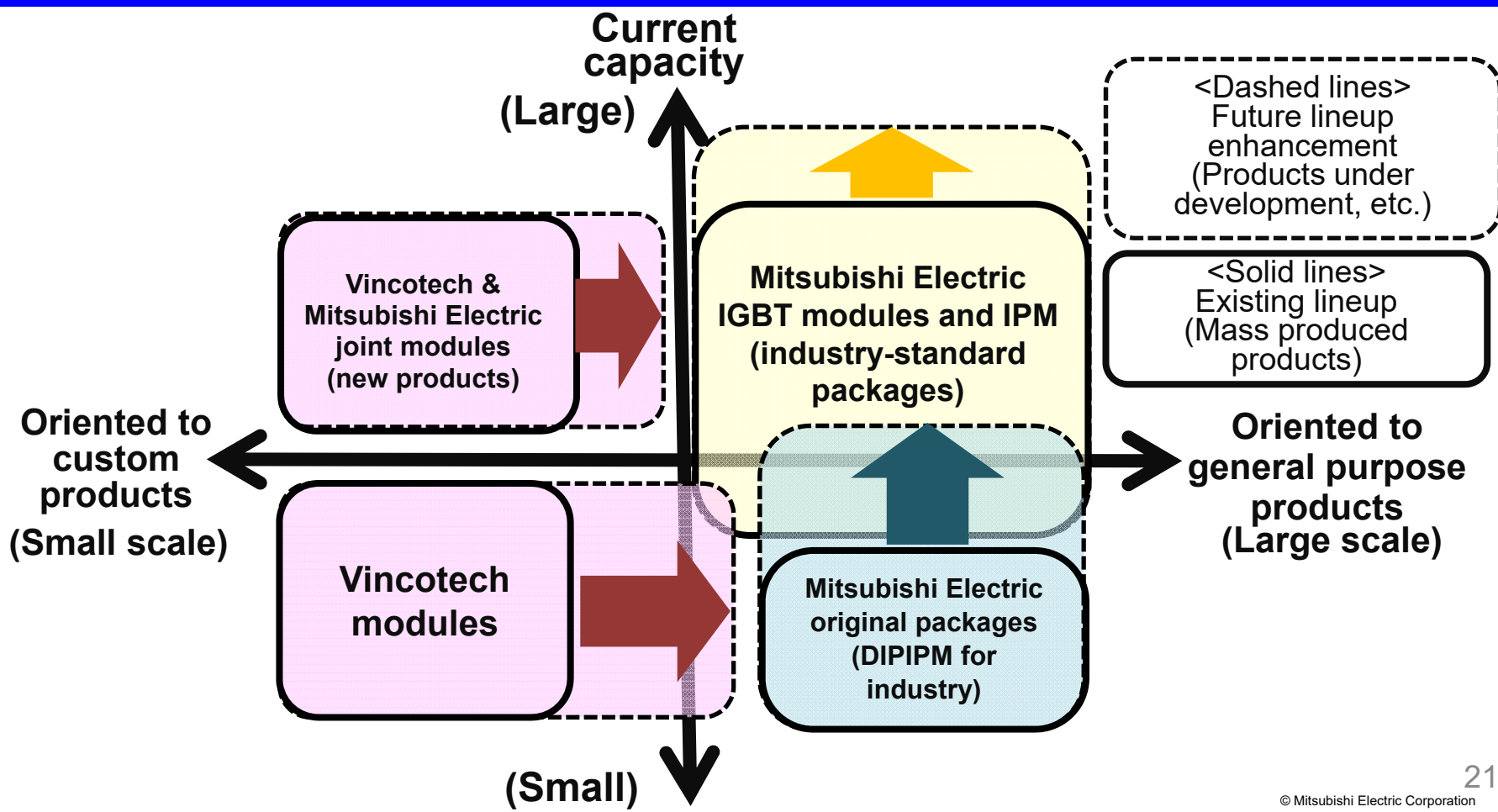
Increase share in major markets for power devices business with competitive products

- Focus on business in European and Chinese markets while maintaining high market share in Japan
- Focus on energy storage, charging, and EV buses as new markets
- Increased strategic original packages in addition to industrial-standard packages
- Increased intelligent products (for IoT*)
- Develop products and synergies with Vincotech (German)

6. Business Strategy by Segment : Industry, incl. Renewable Energy

Product strategy

- *Medium- and large-capacity products: Enhance industry-standard packages and increase capacities*
- *Small-capacity products: Enhance lineup of DIIPM original packages (No.1 among home appliances) and pursue lower costs and higher quality*
- *Transfer medium- and large-capacity technologies to Vincotech to capture custom products market*



6. Business Strategy by Segment: Traction and Electric power



Our strengths and features

*High reliability for
infrastructure*

*Unmatched record and
know-how in high-
voltage segment*

Top record in mass
production of high-voltage
SiC module products*

Growth strategy

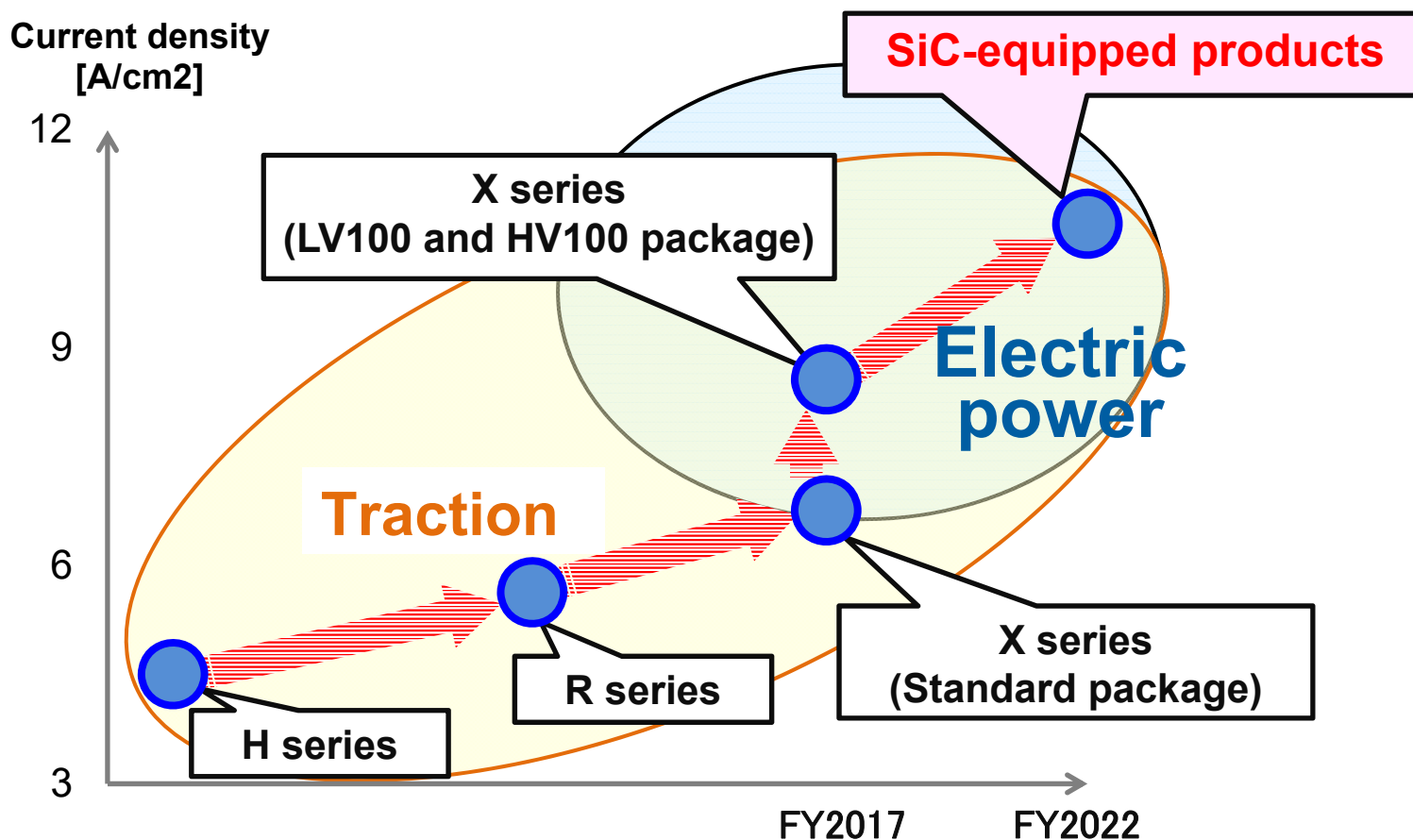
Pursue greater added value in infrastructure segment, where growth is not high but high quality/reliability are demanded, to maintain position as a top supplier

- **Deploy products that utilize latest Si technologies (X series: equipped with first 7th generation 8-inch chips and employs latest packaging technology)**
- **Deploy high-voltage, low-loss SiC module products (3.3kV and 1.7kV)**
- **Continue to develop Chinese and Indian markets, where solid demand is expected for railways.**
- **Focus on DC power transmission, where future expansion is anticipated in Europe, North America and China**

6. Business Strategy by Segment: Traction/Electric power

Product strategy

- Expand applications in traction and electric-power market by introducing products with current densities exceeding those of other makes

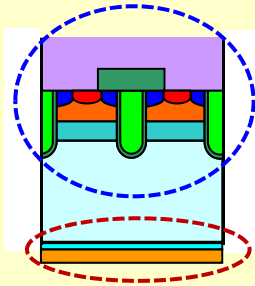


7. Production Strategy : Wafer Production

- Maintain highly added-value processes that are key to differentiation at company factories and continue to make investments (Si wafer back side processing and SiC wafers)
- Maximize production subcontracting (fabrication outsourcing) for Si wafer surface processing involving mainly general technologies and expand capacity while minimizing investments
- Utilize IoT and promote thorough productivity improvements
- Promote transition to multiple production lines to fortify BCP*

Surface processing

Wafer process



Back side processing*

*Process specific to power wafers where electrodes, etc. are formed after grinding back side of wafer

Kumamoto (Koshi City): Mother factory
Wafer-surface and back-side processing
(including SiC)



Hyogo (Itami City)
Si-wafer back-side processing



Fukuoka (Fukuoka City):
SiC wafer (4-inch)
surface and back-side processing

Japan production outsourcing
Si-wafer
surface processing

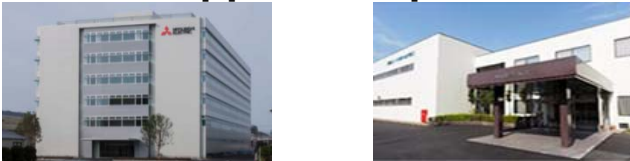
Overseas production outsourcing
(to be decided)
Si-wafer surface processing

7. Production Strategy (assembly/inspection)

- *Establish global system based on local production and consumption*
- *Utilize IoT for thorough productivity improvements*
- *Transition to multiple production lines to fortify BCP*
- *Internalize inspection technologies as know-how and advance them*

Assembly/inspection
processes

Fukuoka (Fukuoka City/Itoshima City):
Mother factory
Automotive/Traction/
Home appliances products



Hyogo (Itami City/Toyooka City)
Industrial products



China (Hefei City/Shanghai City*)
Home appliances products



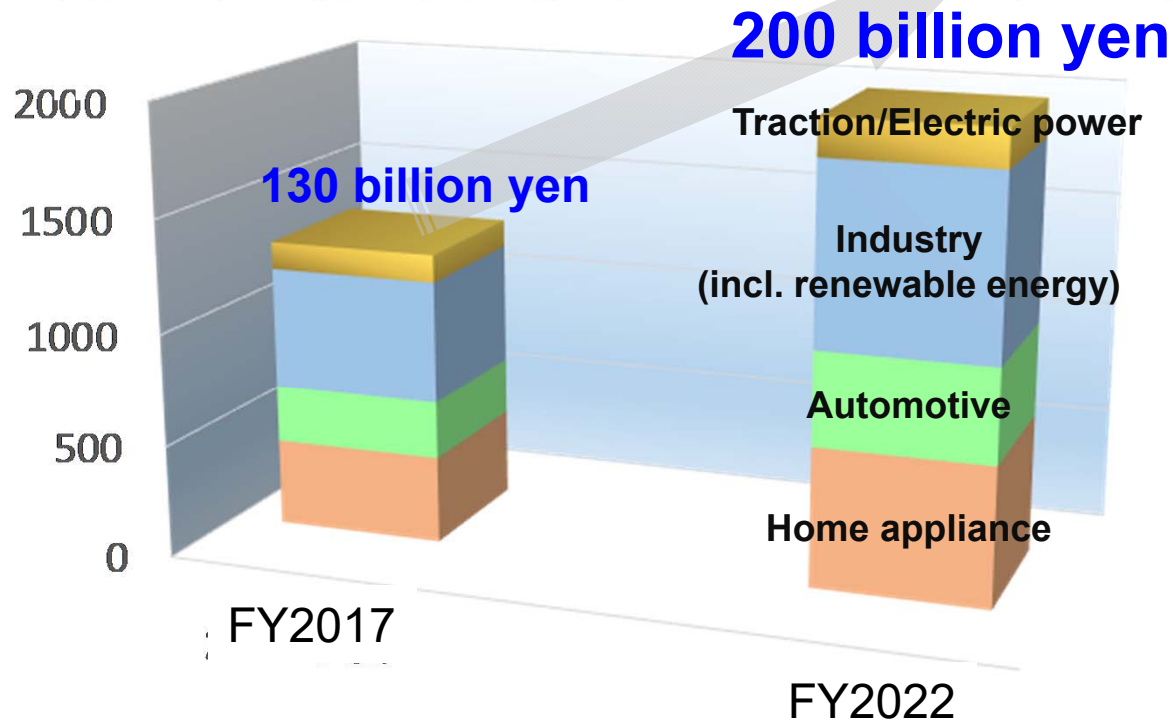
*Outsourcing in Shanghai

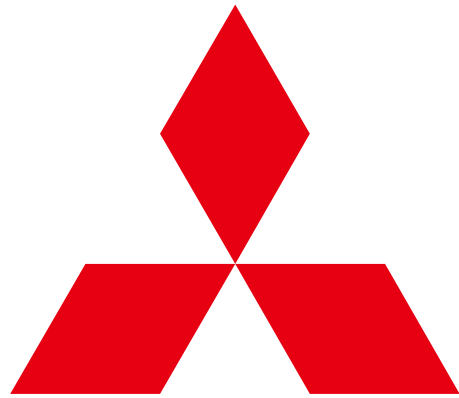
Hungary (Vincotech)
Industrial products



8. Summary

Growth target for “FY2022”
Net Sales 200 billion yen
OPM 10%
Overseas sales ratio 60%





mitsubishi
ELECTRIC

Changes for the Better