



# **Role of Nano-technology for Integrated Power Electronics System**

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# Outline

- **Background : More electrified society**
  - Power consumption and CO<sub>2</sub> emission
  - Horizon of more electrified society
- **Electronics enabling efficient power use**
  - Power electronics as Negawatt
  - Introduction of Negawatt cost
- **Technology scheme of next generation power electronics**
- **Role of Nano-technology for Integrated PE system**
- **Conclusion**

This presentation is based on the 2007 and 2008 NEDO survey researches  
「Green electronics technologies for energy saving society toward 2050」

# Demand for electrical power

Demand for electricity is continuously increasing with economical growth

Trend of electricity consumption in Japan

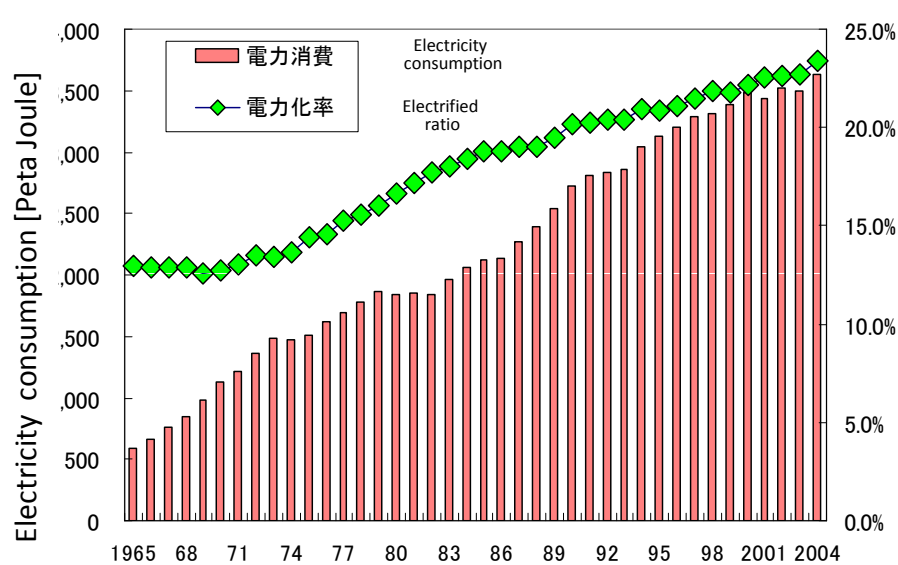


図 2-2 日本の電力消費と電力化率

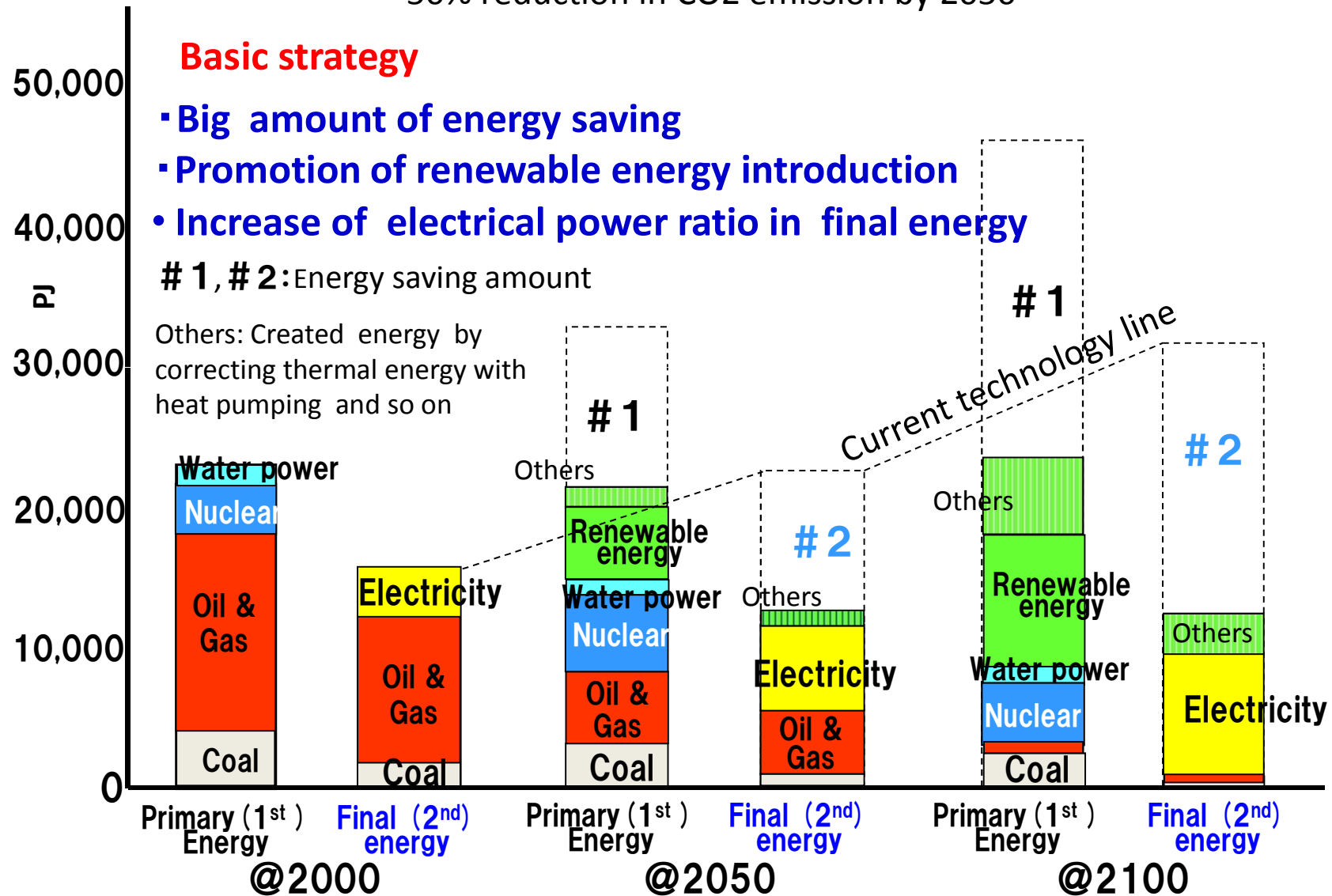
## Back ground of the demand

- Electricity is clean, safe and convenient energy source
- Increase in ICT power consumption
- Expansion of heat pumping usage
- EV, HEV, PHEV
- More electrical power will be supplied by renewable energy

**IEA data also assumes that world demand for electricity will be double by 2030**

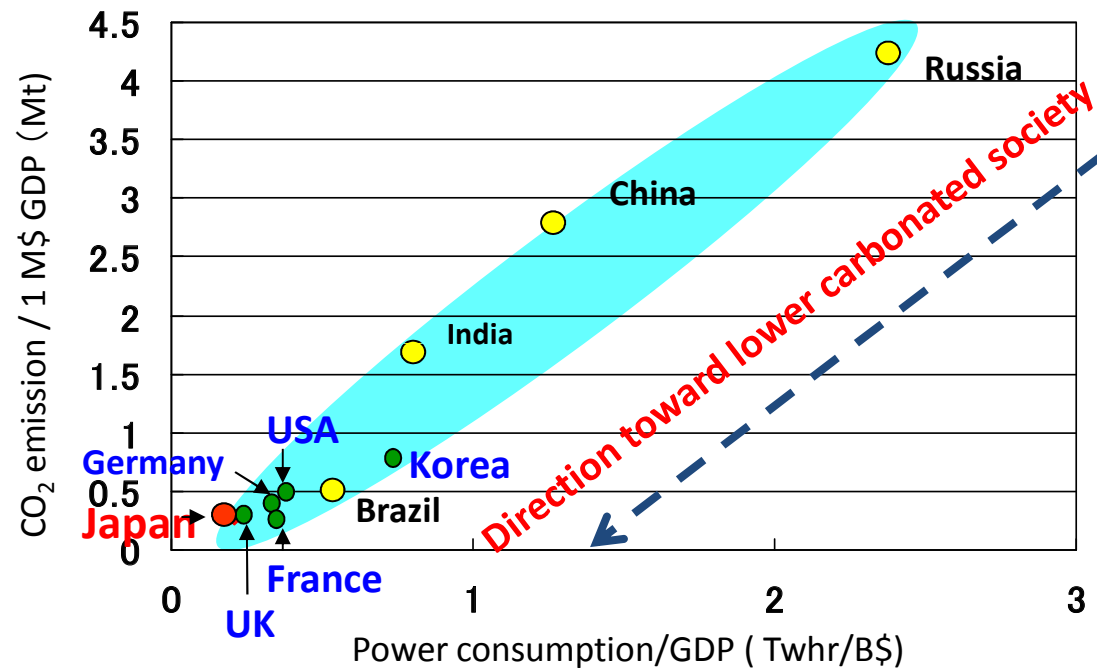
# Long Term Energy Vision of Japan by METI

50% reduction in CO2 emission by 2050



# What we can do for more electrified society

More electrified society make possible sustainable development

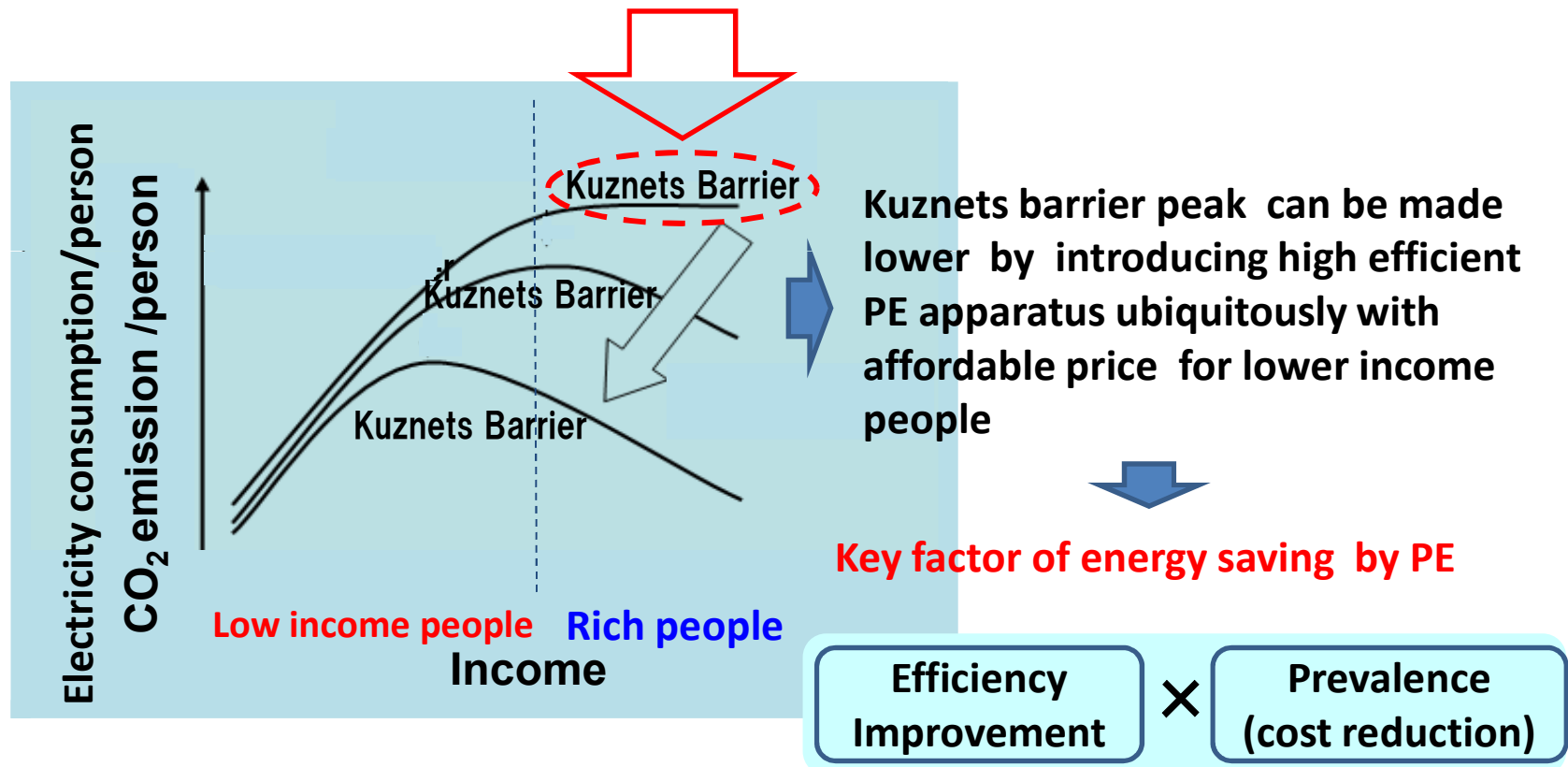


## Two issues to achieve more electrified society

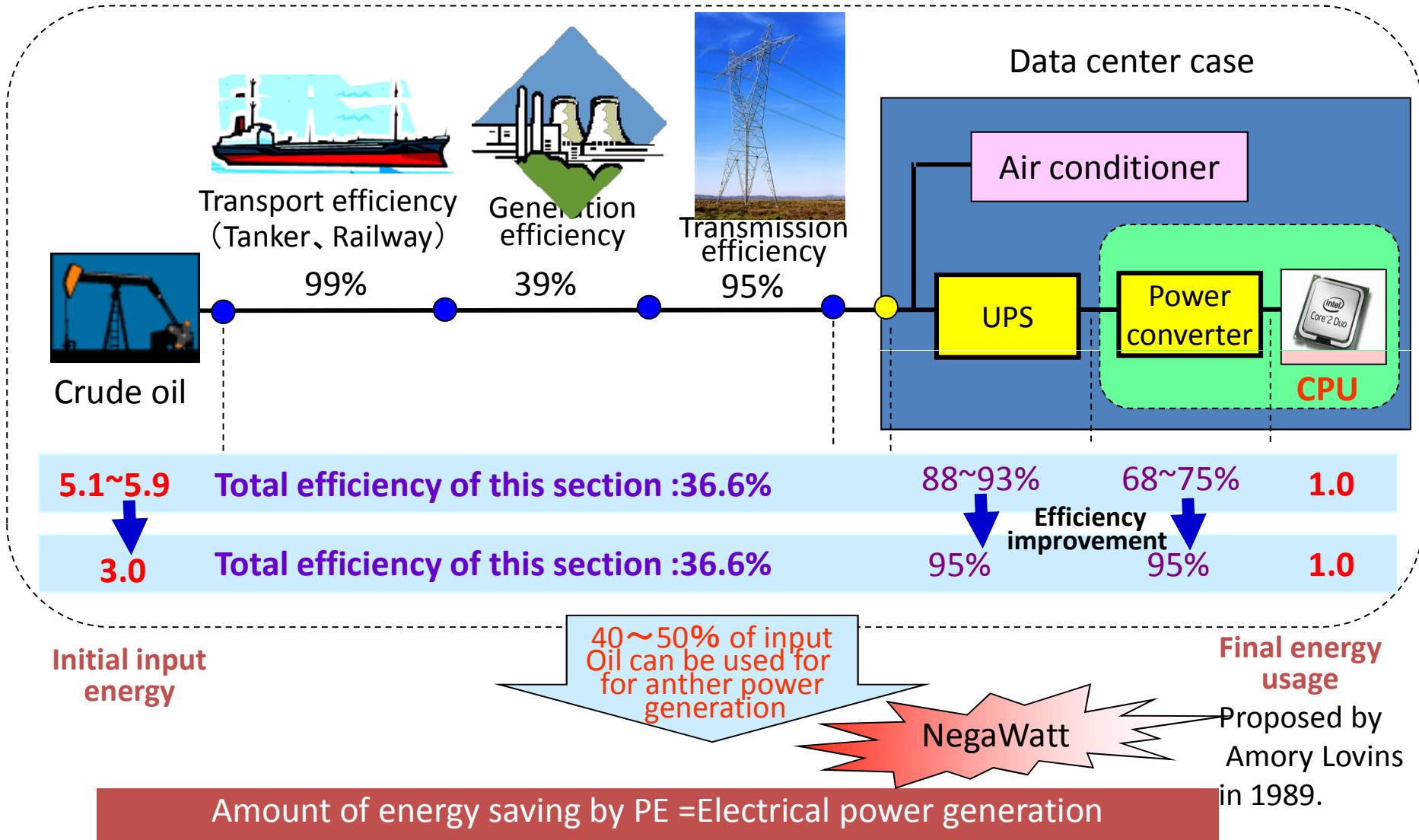
- ① Reduction of power consumption /person
- ② Total energy saving as whole in a society

# Issues of advanced countries in energy saving

Power consumption /Person of advanced countries is still high

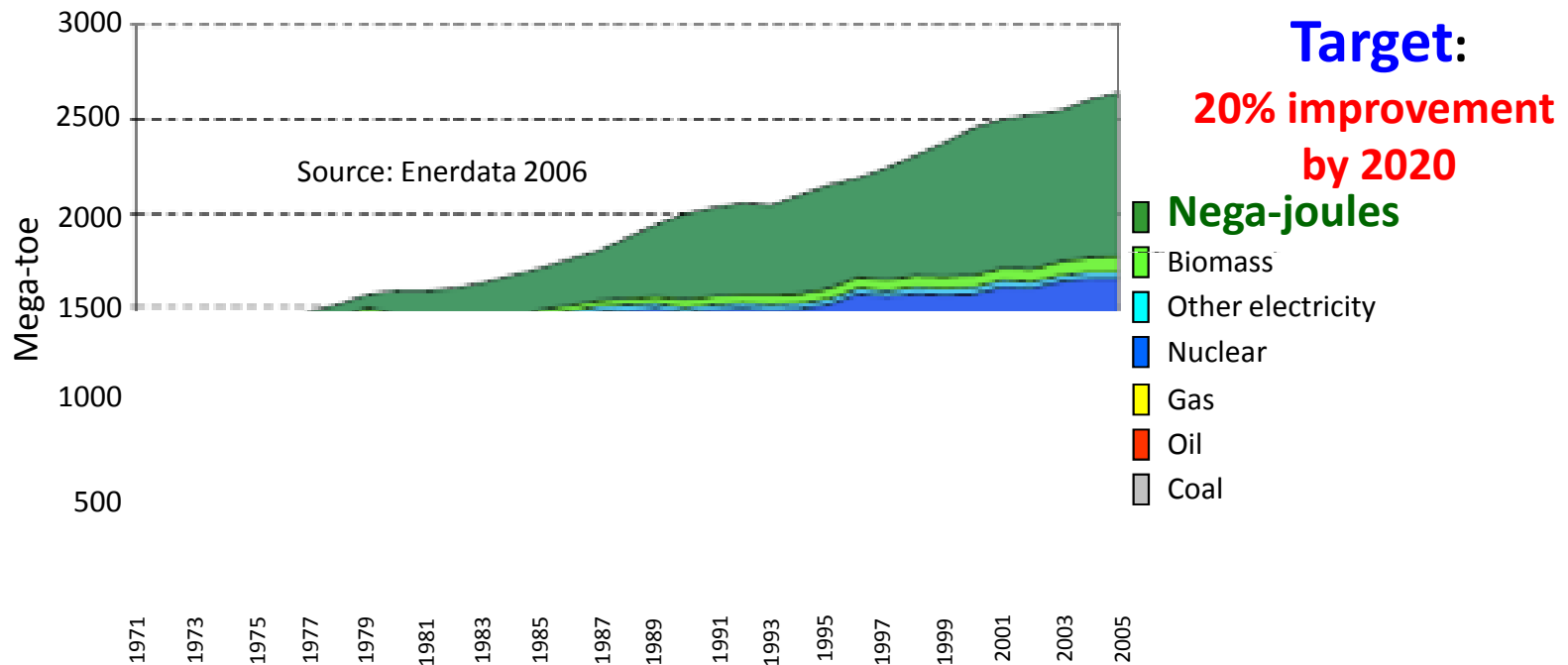


# Power electronics as Negawatt



# Primary energy demand of EU supplied mainly by Nega-joule

(“Negajoule; energy saving calculated on the basis of 1971 energy intensity)



出所: EEAP6 (Action Plan for Energy Efficiency) : Realizing the Potential  
Commission of the European Communities, COM(2006)545 final, 2006





**Negawatt cost definition**  
**as index for wide use of PE technology**

$$\text{Negawatt cost} = \frac{\text{Systemcost} + \text{Runningcost}}{\text{Saved enegy} \times \text{Operationtime (kWhr)}}$$



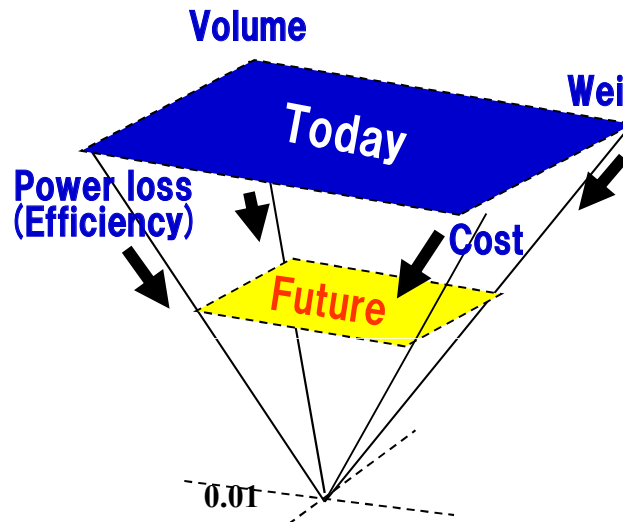
## Negawatt cost comparison

Payback time of power electronics equipments is sufficiently compete with another renewable energy

**PE Nega Watt cost** **10.6 US-cent/kWh**  
**(2.8kW Air-conditioner)**

- **Coal Steam GN. (500MW)** **4.3 US-cent/kWh**
- **PV(5MW)** **41.6 US-cent/kWh**
- **PV(300W)** **56.1 US-cent/kWh**
- **Wind turbine (100MW)** **5.8 US-cent/kWh**
- **Wind turbine(100kW)** **19.7 US-cent/kWh**

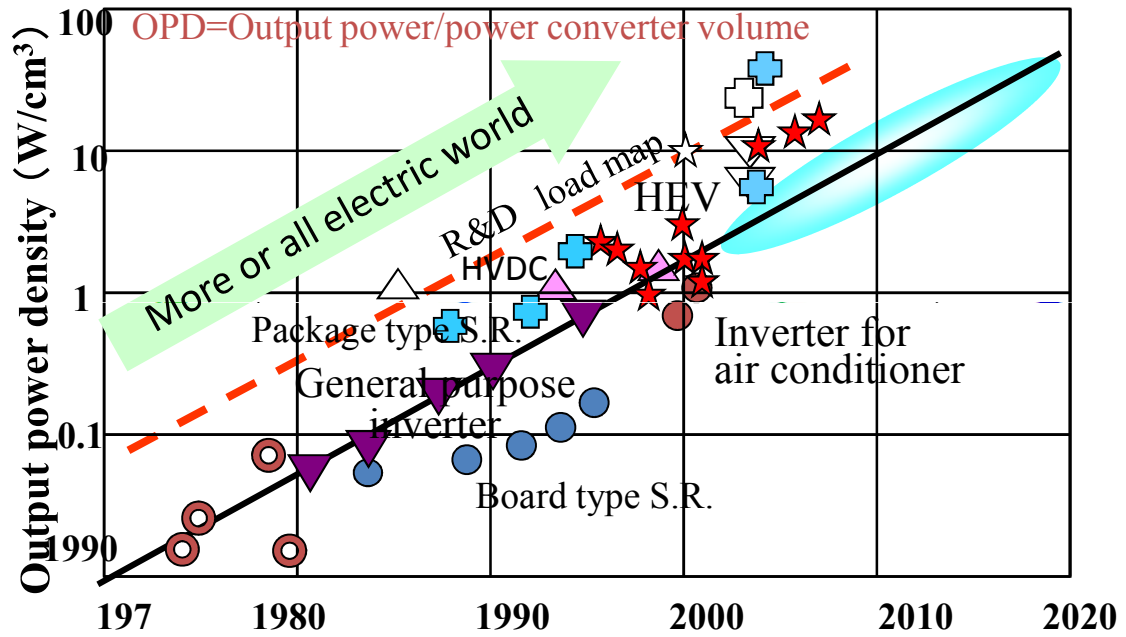
# PE system integration as means of Negawatt cost down



Power density :  $P_o/\text{Volume}$  [W/cm<sup>3</sup>]  
 Watt cost :  $P_o/\text{cost}$  [W/\$]



Same analogy with VLSI prev:  
 Bit density, Bit cost



H. Ohashi IEEJ, 122 No.3(2002)168 H. Ohashi JAPP, 73 NO.12 (2004)1571.

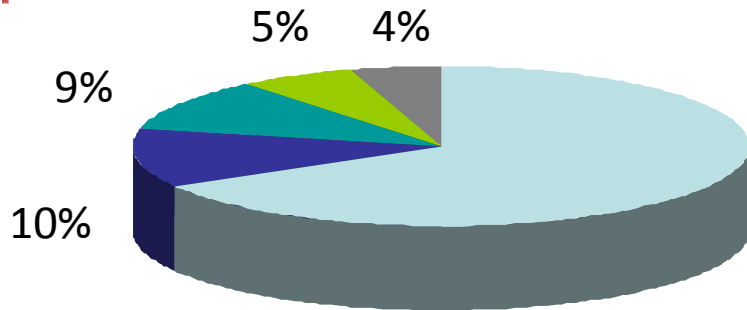
**Power density has been increasing  
by 3 of figure in the last 40 years**

# Integrated PE system is now actually prevailing in market



Bip. M: 270M\$  
 IGBT M:900M\$  
 IPM:780M\$  
 Integrated M:200M\$

## High power density power module



Market data : ISPSD'08 by T. Stockmeier



Toshiba high power converter unit



10kW Rectifier ECPE



TOYOTA Power control Unit

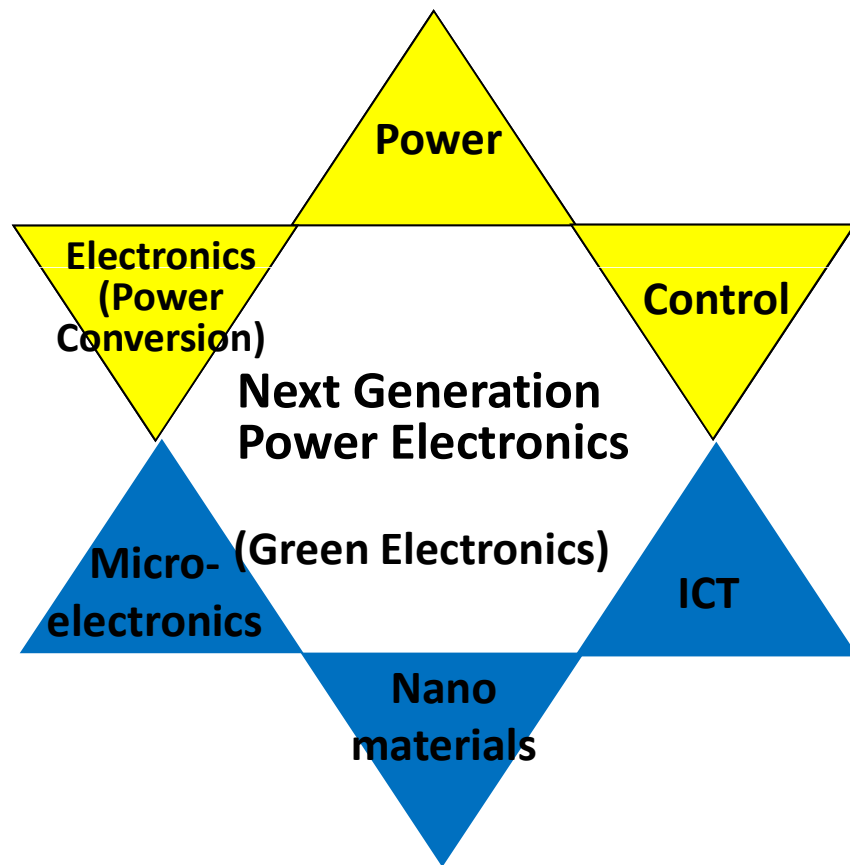
## Integrated PE system

- Motor Drive
- Traction
- Consumer
- Renewable
- Automobile

Market growth :25%

Market growth:19%

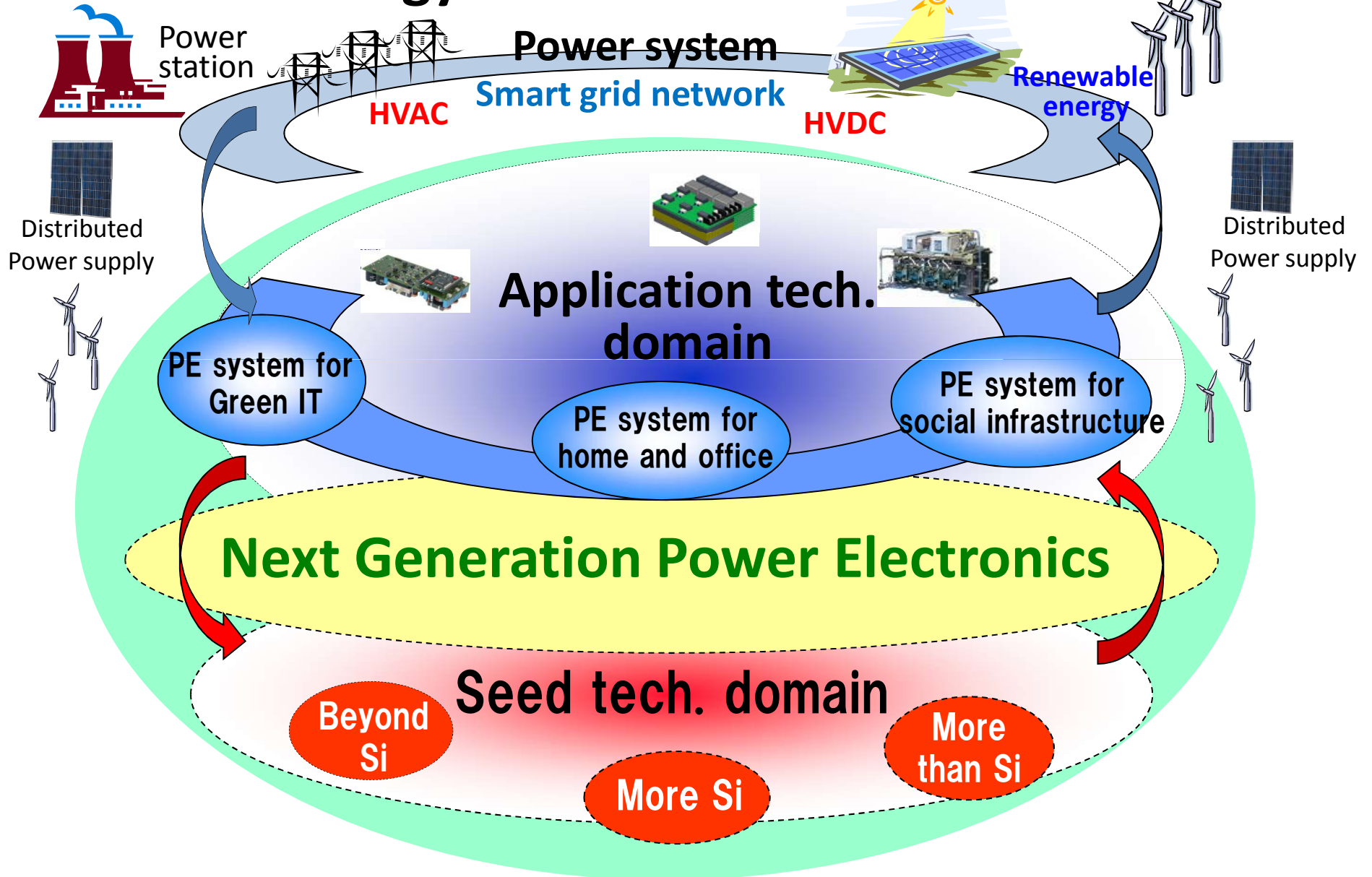
# Definition of Next generation Power Electronics



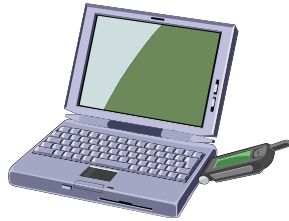
an interdisciplinary technology  
integral of disciplines of electrical  
engineering; PE, microelectronics,  
electronics material and ICT for  
efficient and effective use  
of electricity.

By H. Ohashi Proceeding of EPE 2010

# Technology scheme for Next Generation PE



# PE system for Green IT



PC

Intelligent Office apparatus

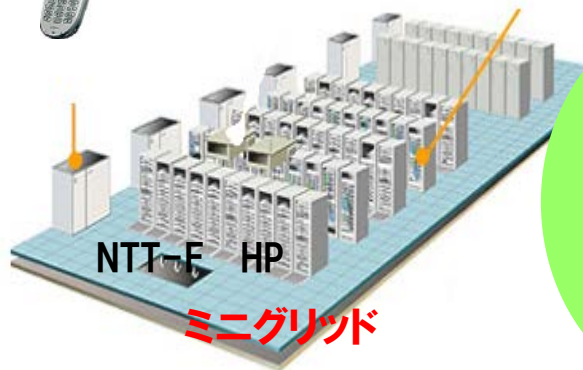
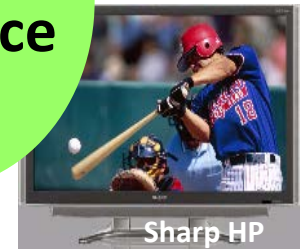


Wearable ICT terminal

Electronics function diversity

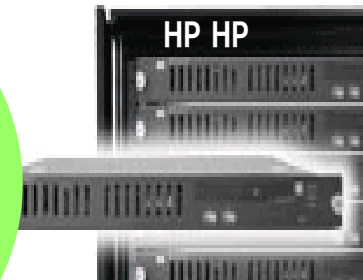
Various electronic functions  
Are Installed inside of  
ICT instruments  
Power management  
inside of ICT instruments  
is becoming more complex

Digital appliance



Data Center

High end server

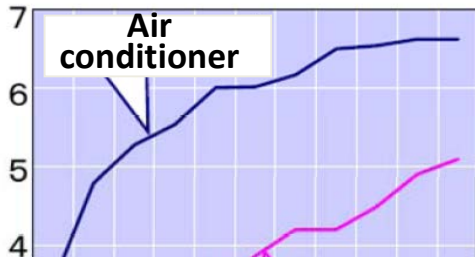
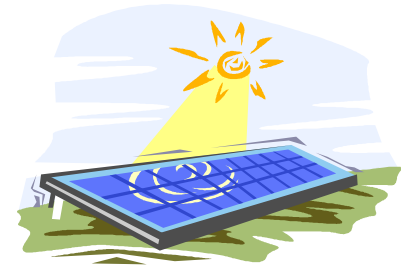


# PE system for home and office

Next generation power supply system

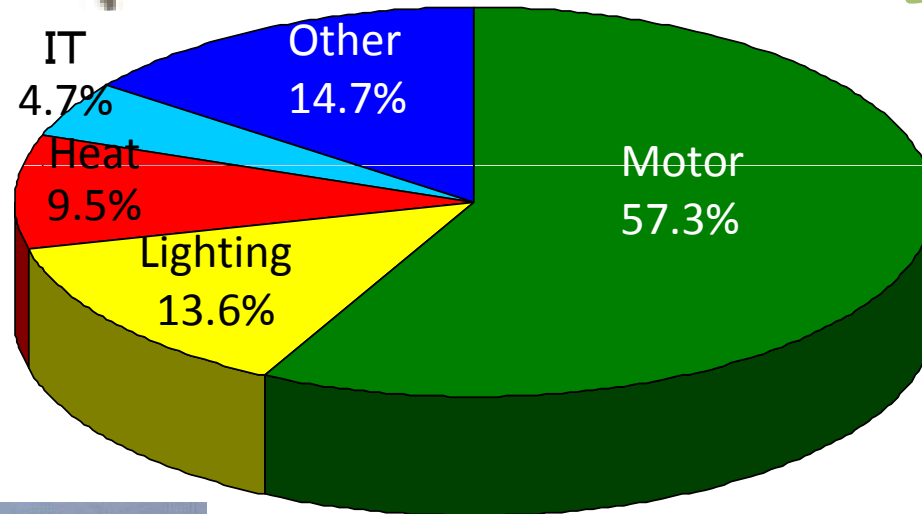


Renewable energy system



Boiler with H.P. system

Super HF Heat pump system



2005 (1T kWh)

FED Survey report (2008)

Next generation motor system



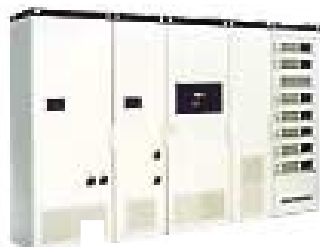
Next generation lighting  
Low power loss flat display



# PE system for social infrastructure



**BEMS/HEMA**



**Next generation  
Motor drive for  
industry**



**Modal shift**



**New grid  
Micro-grid, Smart grid**

## Driving force

- Higher power density
- Lower watt cost

## Approach

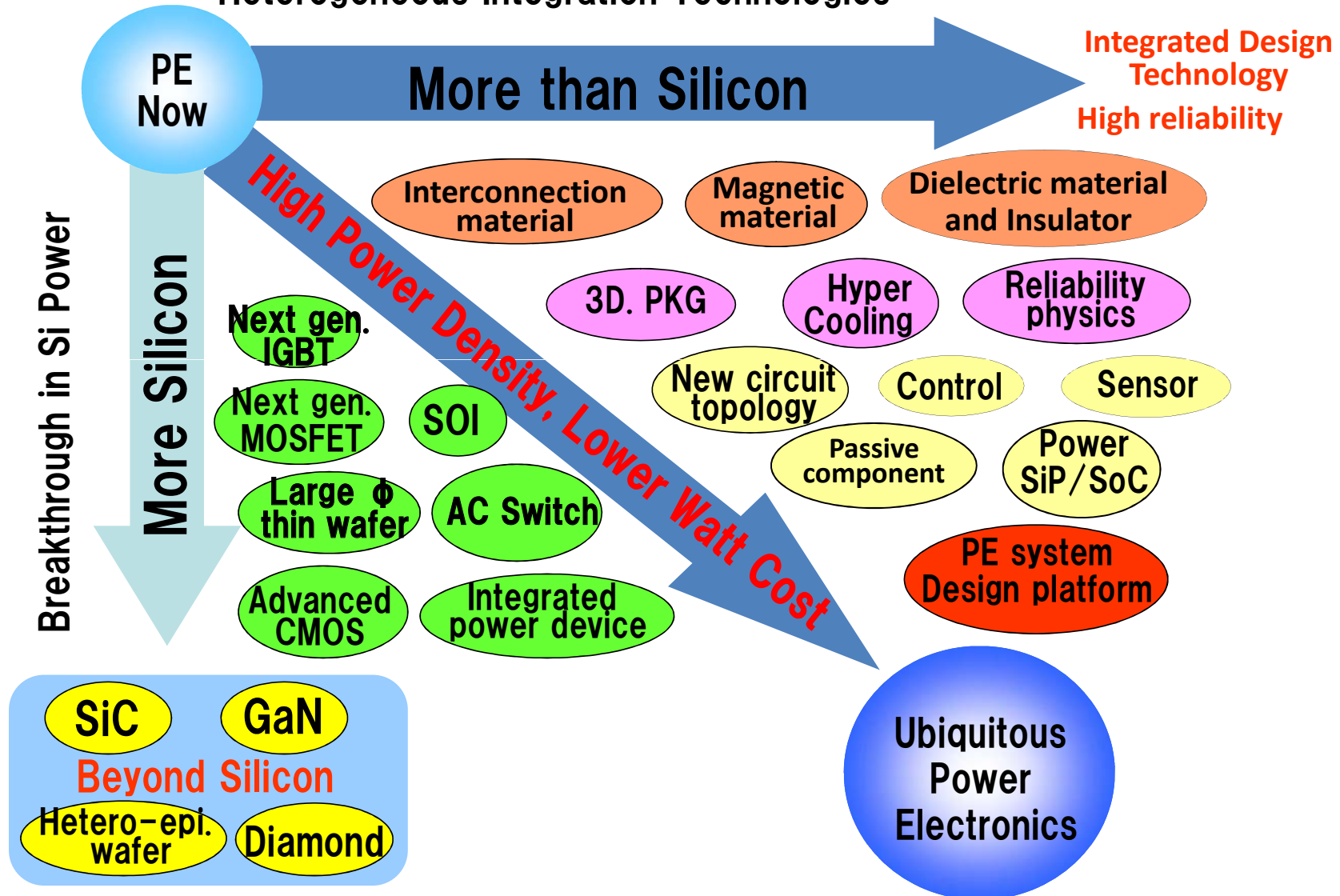
- Standardized compact high power converter

## Seed

- High voltage low loss power device
- high frequency magnetic materials

# Technology map for green electronics

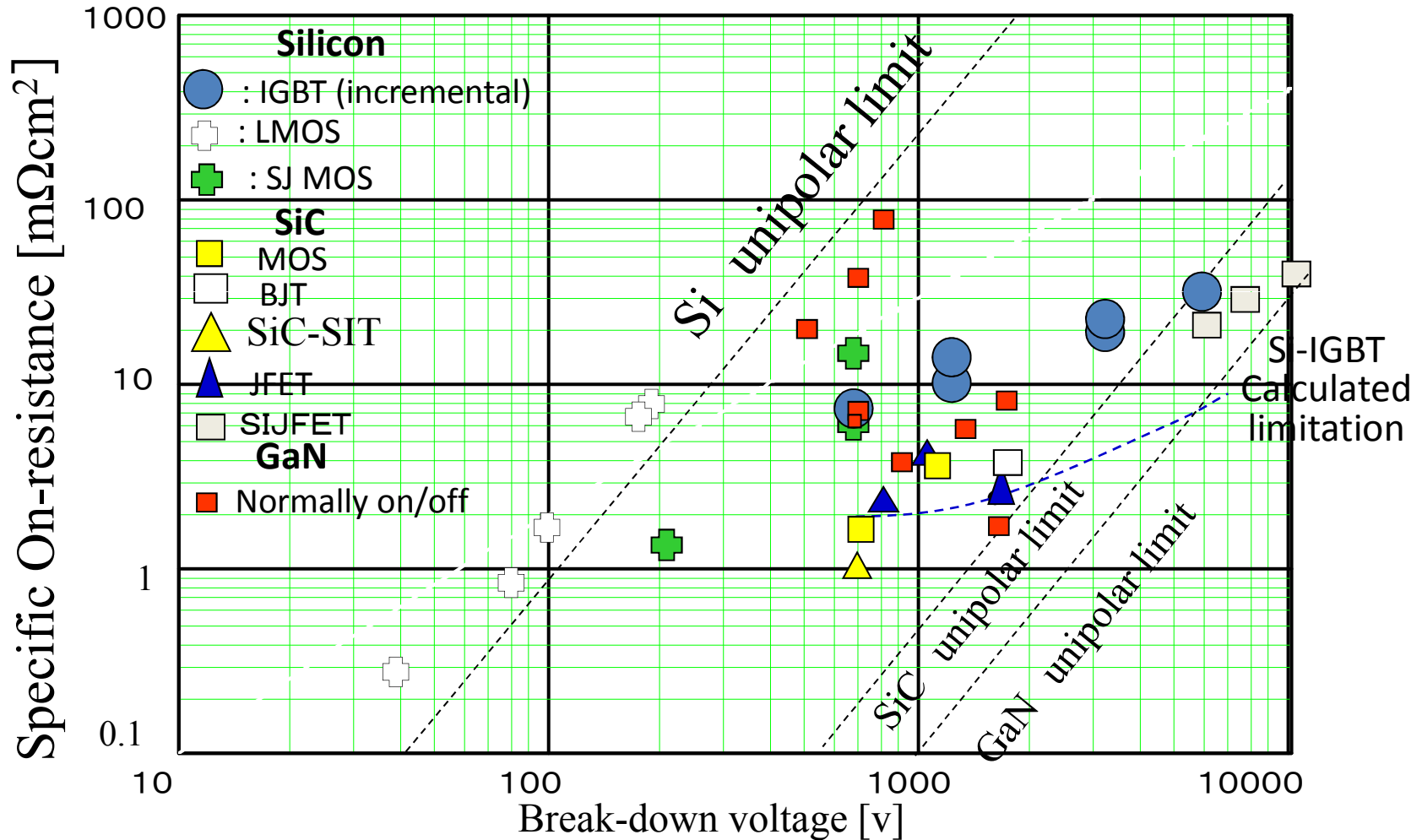
Heterogeneous Integration Technologies



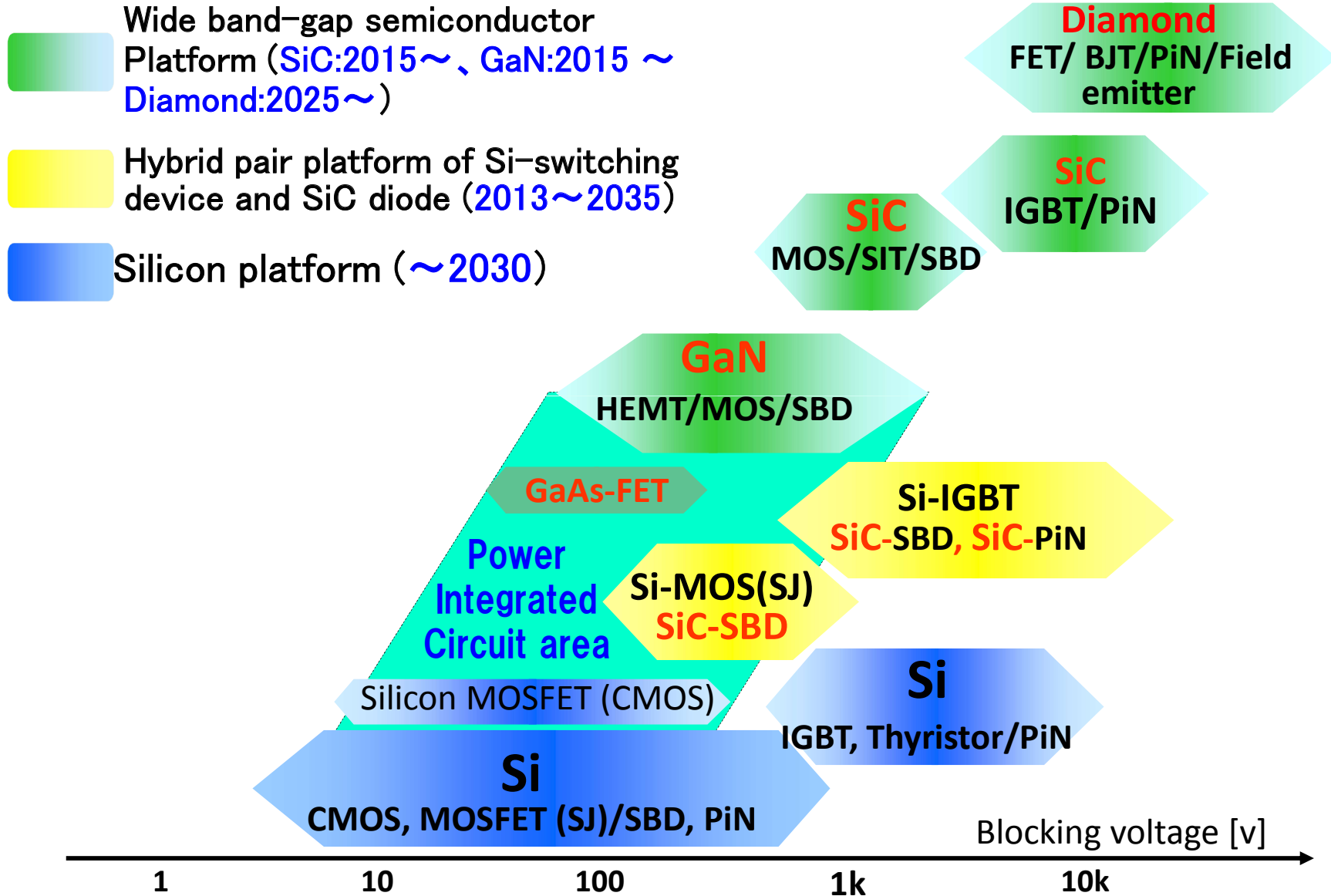
# Trend of advanced power devices

## Comparison in on-resistance

Source: International Symposium on Power Devices & ICs (2006-2009)

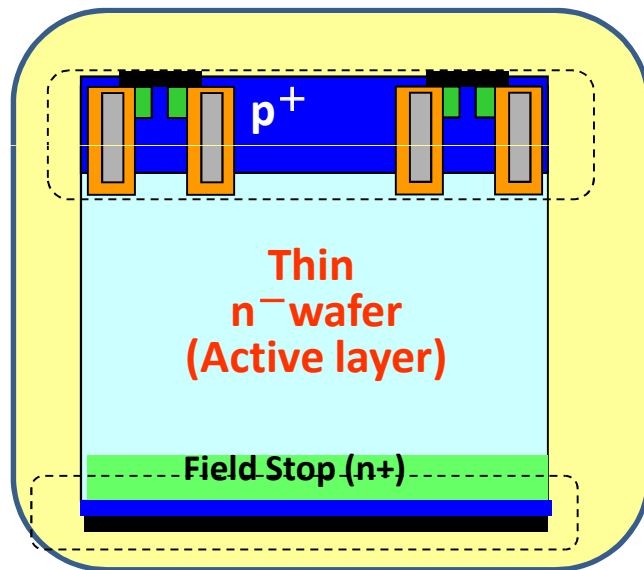


# Road map of advanced power devices



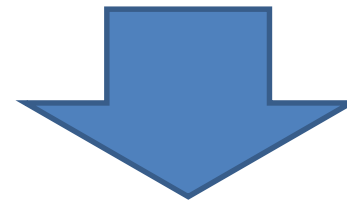
# Approaches for Si-Ultimate IGBT

**Narrow & Deep Trench**



**Transparent p-emitter**

Ideal IGBT performance  
by active layer flat carrier  
distribution



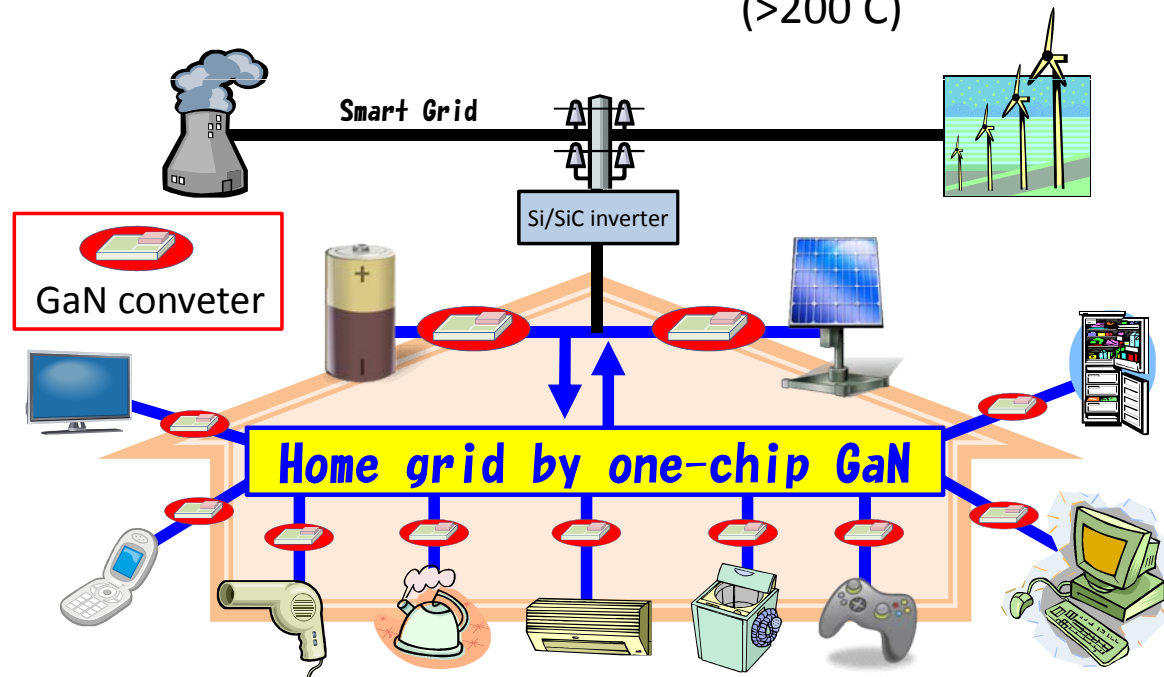
- Several tens nm trench technology
- Reduction of atomic scale complex defect
- Perfect quality large size thin wafer

# Monolithic GaN power system covers most of PE application of Home and office apparatuses

Several hundreds  
Si Power ICs

GaN power ICs

- ◆ High power (> 3kW)
- ◆ High speed switching (>10 MHz)
- ◆ High temperature operation (>200 C)



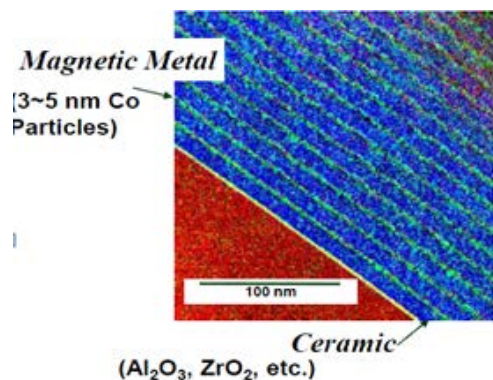
# Nano-material Technologies

Passive components will be next significant issues to be solved for Negawatt cost reduction



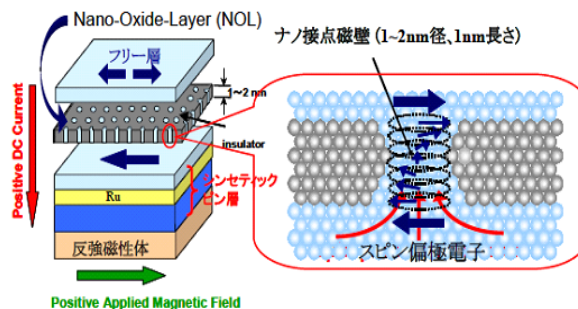
Drastic improvements of inductor, capacitor and transformer are expected in performance, volume, size and familiarity with semiconductor processing by Nano material technologies

## Magnetics



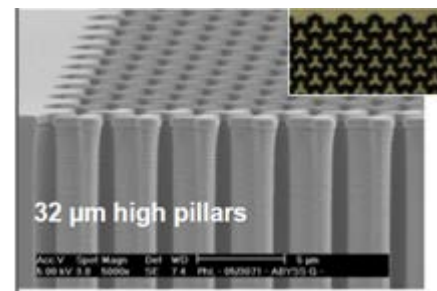
Ferro-magnetic coupled particles

## Inter chip connection by wireless transmission



Spin torque oscillator  
(By Prof. Sahashi)

## Dielectric materials



From layer to 3-D structure

# Conclusion

- **Highly electrified society can make possible low carbonated society, keeping sustainable growth of society**
- **Power electronics as Nega watt makes great contribution for energy saving, by reducing Negawatt cost.**
- **Power electronics system integration is key approach for efficiency improvement and prevalence of PE electronics apparatus with Negawatt cost reduction.**
- **The emerging next generation power electronics is making up of ME, Nano- materials, ICT and conventional PE technologies**
- **Most of issues in the next generation PE will be mainly broken through limitation of semiconductor devices, passive components**





**We will come all of people who are involved in the Nano-  
technology to the next generation power Electronics world!**

**Thank you**