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Future role of power Semiconductors: From "Silicon vs. WBG" to "Silicon and WBG"

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1. Efficiency: Key to reducing future CO2 emission

"Efficiency" is the key issue for power electronics and power device technologies toward future reduction of CO2 emission by reducing energy consumption. Information and communications technology (ICT) industry is a good example to show the importance of improving the efficiency. (In a data center ([1]), total energy efficiency is less than 30 percent.) The potential of energy efficiency improvement in end-use-energy is listed at the highest among the other options in IEA report ([2]) as measures for reduction of CO2 emission.

2 "Efficiency" as renewable energy resource "Negawatt"

One of the most important role of power electronics technology in the future advanced electrification are as "efficiency improvement driver" in electric and electronic systems. Once efficiency is improved in a system, a part of the wasted heat energy in the old system is converted to electricity equivalent to energy generated without CO2

If we accept energy efficiency improvement as energy resource, the generated energy by the efficiency improvement is equivalent to renewable energy which can be use by another load. This concept is called "negawatt" ([3], [4]). Once negawatt concept is accepted, power electronics as the technology of efficiency improvement driver can be categorize as renewable energy resources, and the cost of technology can be compared with photovoltaic (PV) and wind turbine generators.

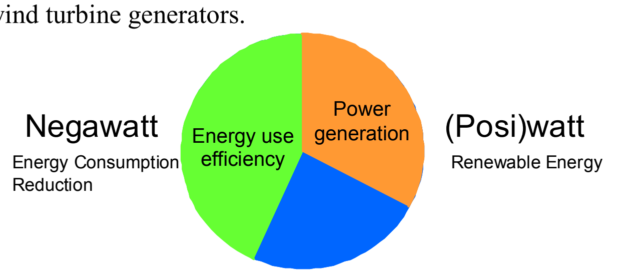

Figure 1 Perspective for potential CO2 reduction for technologies by OECD/IEA ([8], modified)

Let us calculate the negawatt cost. The cost of negawatt by installation of 2.8kW high efficiency air-conditioner, which are one of the most committed application of the power electronics technology, replacing inefficient air-conditioners can be calculated about 10-20 cent/kWh. Although the power electronics related "negawatt" cost is couple of times higher than that of the coal steam generation system, the cost is comparable to PVs and wind firms([5], [6]) if the "negawatt" is considered as renewable energy resouce.

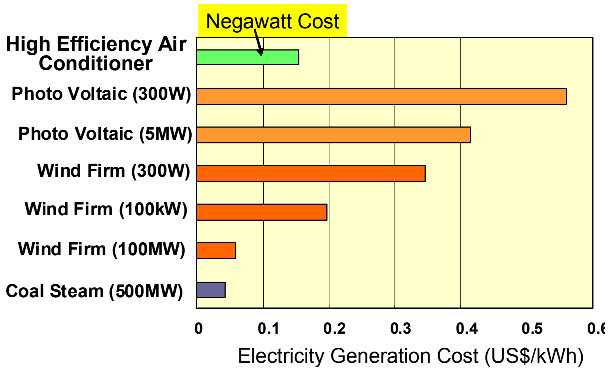

Figure 2 Cost comparison of "Negawatt" with installing high efficiency air conditioner and renewable energy cost.

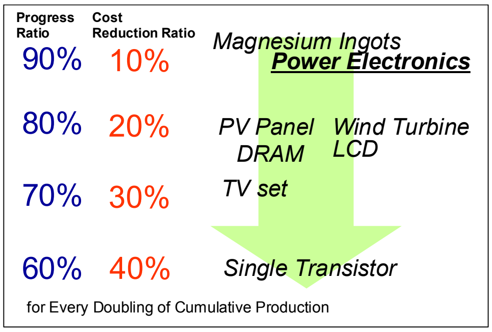

Figure 3 Progress ratios for electric and electronics technologies. The ratio indicate cost reduction speed for every doubling of cumulative production.

3 "Installation" with better progress ratio of "Cost per Negawatt"

The assessment with the experience curve had been often used in policy making and long term marketing to promote new technologies in renewable energy source. Progress ratio (propagation rate) is defined as reduction in cost for every doubling of cumulative installation (production). The progress ratio in the PV module production was calculated to be about 80 percent and learning investment was 60 billion dollars which include government measures to promote PVs, incentive cost for commercialization and recouping of research and development cost([7]).

An investigation shows that progress ratio of inverters is higher than 90 percent which means cost reduction of the power electronics system is rather slower than the other renewable energy systems([8]). Both the initial cost ($/kW) and overall lifecycle cost ($/kWh) reduction with better progress ratio is required to make "Negawatt" break even for the installation without governmental investments.

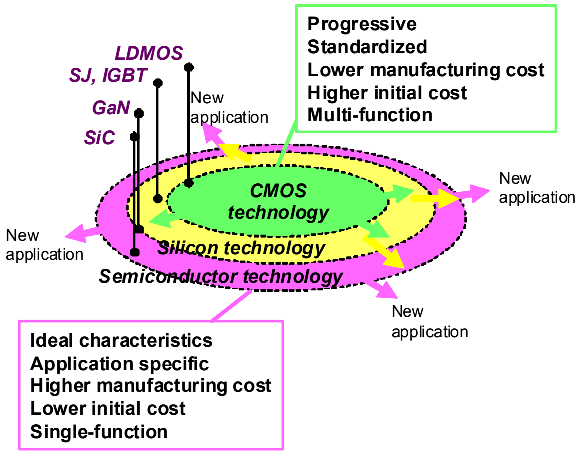

Figure 4 Features for types of semiconductor technologies.

4. Future Role of Power Semiconductors

The "ideal" characteristics of the wide-bandgap (WBG) power semiconductors shows advantage to open new applications in power electronics industry while competitive silicon power technology is characterized as "progressive" toward future volume applications[9]. Among the silicon technologies, CMOS platform becomes very strong once it meets huge volume applications [10, 11]. Based on this analysis, silicon power device industry challenges to prepare future volume demands for end use owned by many people while WGB power semiconductor challenges to open new application of power electronics technology and core power electronics systems (Fig. 5, [12],modified).

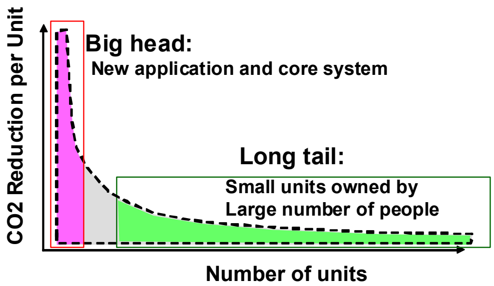

Figure 5 Two segments of technologies for CO2 reduction.

Paradigm of electronics technology has spread from hardware to service for reduction of CO2 emission (Fig. 6). The role of power semiconductors have been re-defined as the key segment for the future environmental technology.

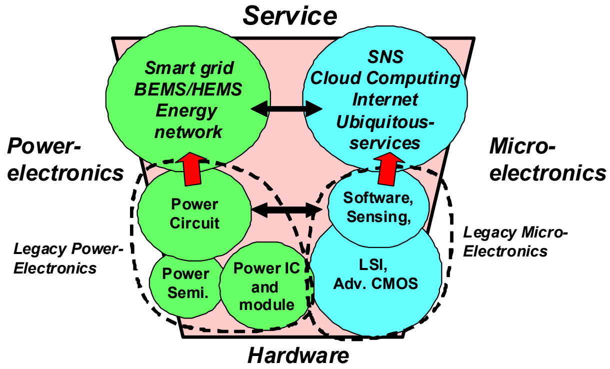

Figure 6 Paradigm shift in semiconductor technologies toward CO2 reduction.

References

[1] Data from presentation by Guy AlLee et al. "Data Center Energy Efficiency," Research @Intel Day 2007 press kit

[2] "Energy Technology Perspectives 2006: Scenarios and Strategies to 2050," OECD/IEA, 2006.

[3] The Negawatt Revolution Keynote Address by Amory Lovins at the Green Energy Conference Montreal 1989. (http://www.ccnr.org/amory.html)

[4] P. Hennicker and D. Seifried,"Das Einsparkraftwerk: eingesparte Energie neu nutzen," Birkhauser Verlag GmbH, 1996.

[5] "Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies", ES-MAP, World bank,

[6] "Energy Efficiency of Air Conditioners in Developing Countries and the Role of CDM" OECD/IEA, 2007.

[7] "Experience curves for energy technology policy," OECD/IEA, 2000.

[8] J. Shaeffer et al. "Learning from the Sun, Analysis of the use of experience curves for policy purpose: The case of photovoltaic power," Final report of the Photex project, Energy research center of Netherlands, ECN-C-04-035, 2004.

[9] R. C. Eden, "25 Years of Digital III-V Technology: A Perspective," IEEE GaAs Digest, 2003

[10] Electronic Journal Oct. 2010 (in Japanese)

[11] A. Pawlikiewicz and S. El Rai, "RF CMOS or SiGE BiCMOS in RF and Mixed Signal Circuit Design," MIXDES '07. pp. 333 – 338, 2007.

[12] World Bank CFU, "Scaling Up Demand–Side Energy Efficiency Improvements through Programmatic CDM," ESMAP Technical Paper 120/07, 2007.