WORLD SCIENCE FORUM BUDAPEST

PLENARY SESSION IV.
"SCIENCE IN THE INNOVATION ECOSYSTEM"

Lighting the World by LEDs and Future Prospects

Venue: Ceremonial Hall, Hungarian Academy of Sciences
9:30-11:00 November 06, 2015 Budapest, Hungary

名古屋大学 NAGOYA UNIVERSITY

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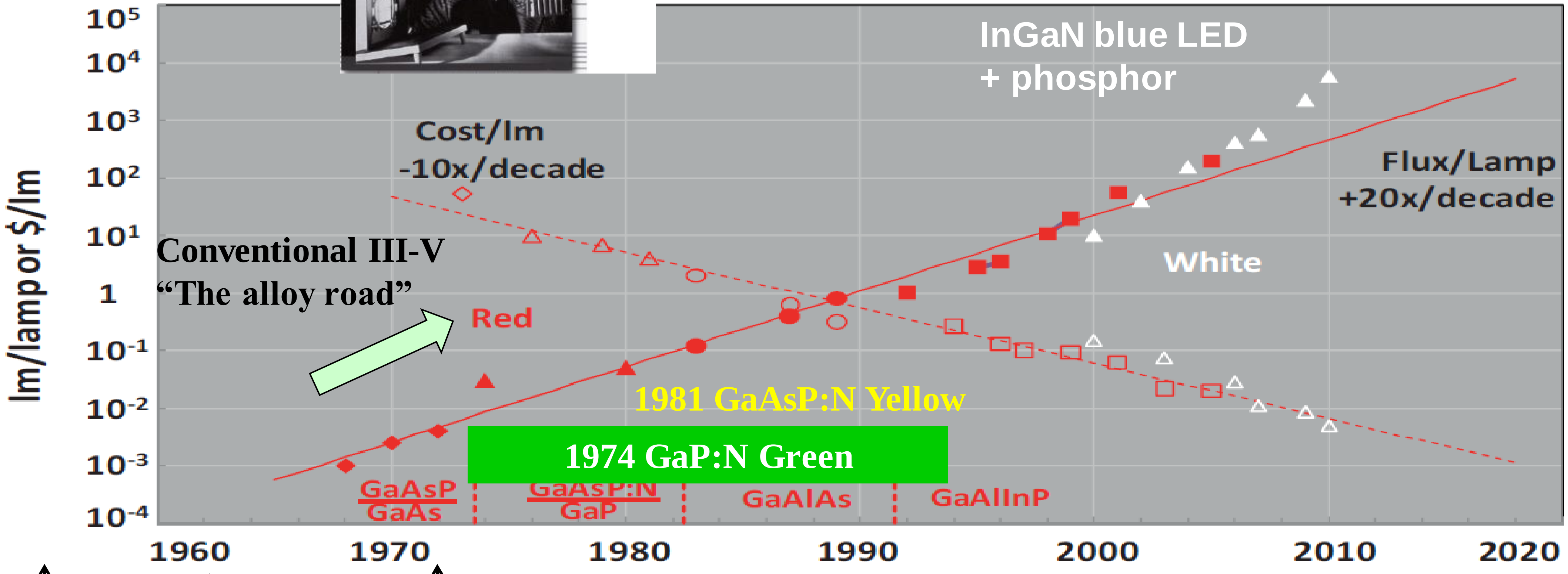
C3-1 Furo-cho, Chikusa-ku, Nagoya, 464-8603, Japan

Overview of development of LEDs

1968 RCA LCD



Conventional III-V
“The alloy road”

1981 GaAsP:N Yellow

1974 GaP:N Green

R. Haitz and J. Y. Tsao, phys. stat. sol. (a)208(2011)17

1971 J. Pankove, GaN MIS LED

1962 N. Holonyak Jr., GaAsP red LD

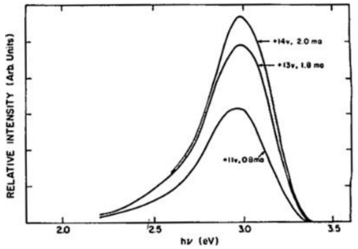
1952 H. Welker, GaAs, GaP

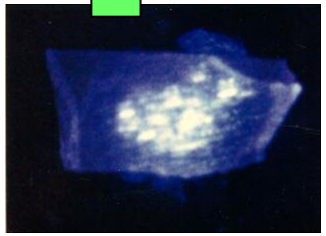
GaN blue LED research in 1970's "Too Early Challenge"

Violet luminescence of Mg-doped GaN **Mg**

H. P. Maruska, D.A. Stevenson, J. I. Pankove

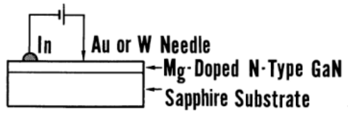
Appl. Phys. Lett., 22, 303 (1973).





http://www.sslighting.net/lightimes/features/maruska_blue_led_history.pdf

Stanford University and RCA



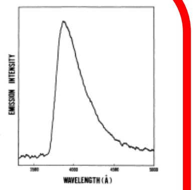


Fig. 4. Typical example of emission spectra. The current is 10 mA. The measurements were done at room temperature.

Mg

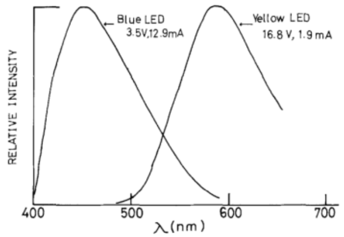
JAPAN. J. APPL. PHYS. Vol. 13 (1974), No. 8

Violet-Electroluminescence from Mg-Doped GaN Point Contact Diodes

Yasuo MORIMOTO

Research Laboratory, OKI Electric Industry Co., Ltd.

Oki Electric



Optical Properties of GaN Light Emitting Diodes **Zn**

Akira Shintani* and Shigekazu Minagawa*

Hitachi, Limited, Central Research Laboratory, Kokubunji, Tokyo 185, Japan

J. Electrochem. Soc., 123 (1978)1725.

Hitachi

Zn

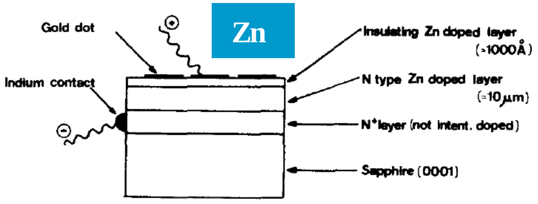
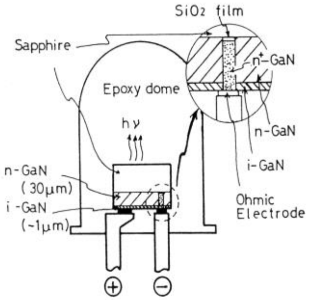


FIG. 3. Structure of the electroluminescent device.

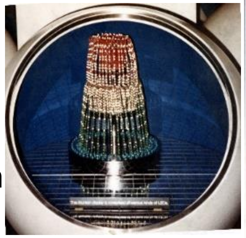
G. Jacob and D. Bois, Appl. Phys. Lett., 30 (1977) 412.

Philips



Zn

Matsushita Research Institute, Tokyo (Panasonic)



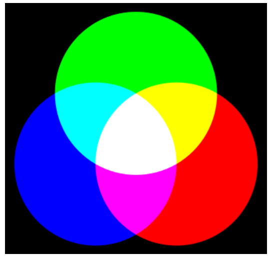
May 1981, New York

Y. Ohki, Y. Toyoda, H. Kobayashi and I. Akasaki, Intl. GaAs Symp., 479-484 (1981)

Long history of the development of white LEDs

Isamu Akasaki
1967 AlN powder
1981 Nagoya Univ.
1992- Meijo Univ.
(Prof. Emeritus Nagoya Univ.)

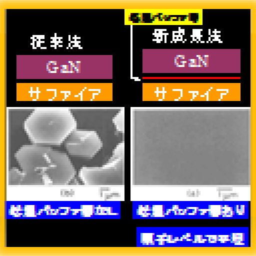
Shuji Nakamiura
(Nichia, now UCSB)



Wide-gap GaN
Blue LED

1959 Research
Seed of blue LED

30 years
ago !



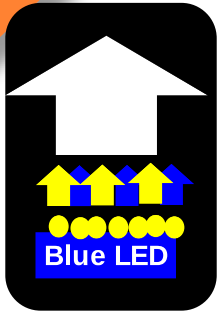
Nichia

1989-1993：LT GaN
p-type by thermal annealing
InGaN/GaN DH

Three primary colors

Nichia

1996：
White LED



Yellow Phosphor

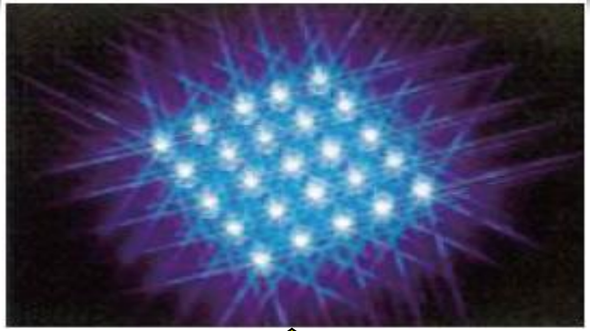
1985 LT buffer (MC)
1989 P-type GaN (Research Associate)

1987 JST
1995 Commercialization

Toyoda Gosei

Hiroshi Amano
1988 RA, Nagoya
1989 Dr. of Eng., Nagoya Univ.
1992-2010 Meijo Univ.
2010 Nagoya Univ.

Partnership between industry, government and academia



Contribution to energy savings !

1995 Production Technology Development

TOYODA GOSEI

Collaboration

1987 Promotion of Research and Development

JST Japan Science and Technology Agency

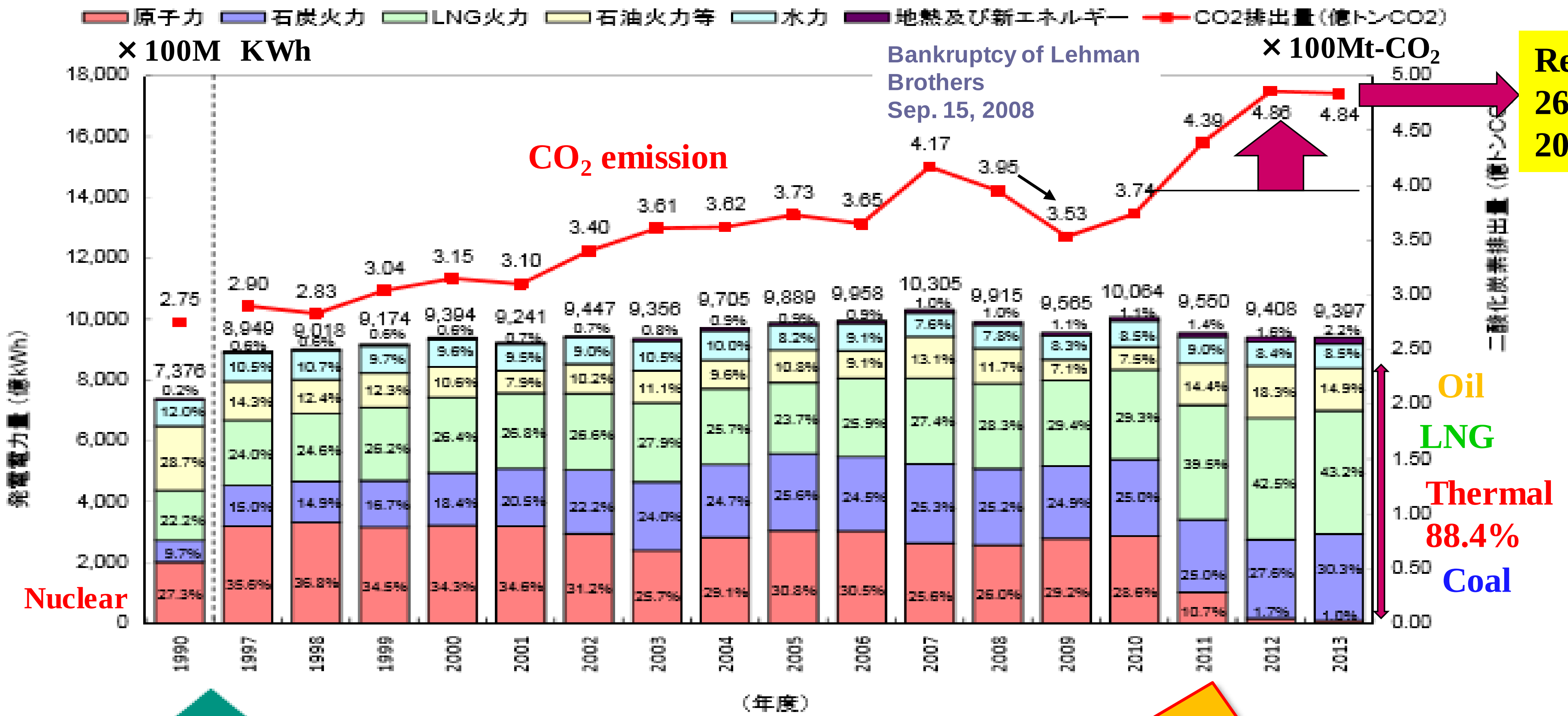
1985 Fundamental Research Achievement

NAGOYA UNIVERSITY

How LEDs contribute to saving energy and environment

Electricity generation and CO_2 emission in Japan

April 2015 Report



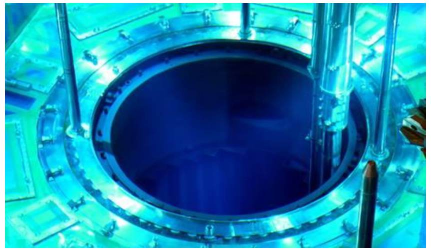
Reduce 26% by 2030 !

March 11, 2011
Great Earthquake attacked East Japan

環境省
Ministry of the Environment

Sendai No.1, No.2 reactors under operation

August 11, October 15, 2015



http://blogs.wsj.com/japanrealtime/tag/sendai-nuclear-power-plant/

Sendai
No.1, No.2 Reactor
890,000 KW × 2

The No. 1 reactor at Kyushu Electric Power's Sendai power station, shown here, is set to become the first reactor to operate under tighter safety regulations that Japan adopted following the Fukushima disaster in 2011.

The No. 1 reactor at Kyushu Electric Power's Sendai power station, shown here, is set to become the first reactor to operate under tighter safety regulations that Japan adopted following the Fukushima disaster in 2011.

8-16 TWh
(300 TWh in Japan, before 2011)

2.2-3 T JPY for safety system, Impossible to collect within 40 years of operation

原発の資産価値と安全投資額（電力9社）単位は億円

電力会社	原発名	原発の資産価値	安全投資額	安全投資の回収に対する各社のコメント
北海道	泊	2247	1600	最古の原発でも運転開始後２５年。投資に見合う十分な価値がある
東北	東通 女川	2587	1540	電気料金での回収可能性や、再稼働に伴うコスト削減効果を総合的に勘案して実施
東京	福島第１ 福島第２ 柏崎刈羽	5388	− 1412 4700	残りの運転年数で回収できるか、電力自由化後も、市場価格との比較で回収可能かなどの観点から判断する
中部	浜岡	1711	3000	電気事業会計規則が改正され、一部設備について運転終了後も減価償却が可能になった
北陸	志賀	1677	1100	原発は新しい。運転期間を考えると回収は可能
関西	美浜 大飯 高浜	533 1729 1025	約3000	安全投資および回収については、今後の対応を検討していく。現総額については、決まったものではなく変動する可能性がある
中国	島根	751	2000	廃炉措置に必要な財務基盤を確保すべく、電気会計制度が見直された
四国	伊方	1073	1200	投資の大部分は３号機。再稼働すれば、安全・安定的な運転で回収は可能
九州	玄海 川内	1459 646	3000超	安全投資に伴うコスト増分を考慮しても、ほかの電源に比べ、原発の燃料費は安く、優位性がある
９社合計		約2兆800億円	約2.2兆円	―

※原発の資産価値については、発電所ごとの公表・未公表が各社で分かれた

http://qbiz.jp/image/box/5dbdf2875679ea80f856b23bedc5614b.jpg

CO_2 emission ↓
LNG import ↓
Safety ?
Cost ?

IEEJ report July 10, 2015

How InGaN LEDs contribute to saving energy

Table ES. 1 Total U.S. LED Forecast Results

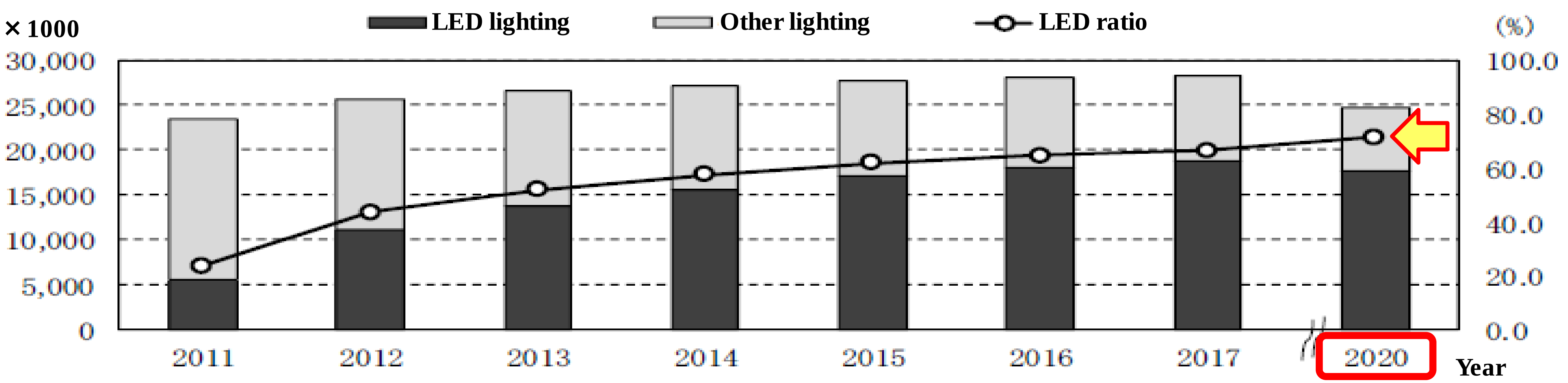
	2010	2015	2020	2025	2030	Cumulative (2010-2030)
Baseline site electricity consumption (TWh)	**694**	**635**	**631**	**641**	**648**	**13,535**
Residential	173	142	138	146	153	3,105
Commercial	346	325	321	320	316	6,806
Industrial	58	49	44	41	38	947
Outdoor Stationary	116	119	128	135	141	2,676
LED market share (% of lm-hr)	**-**	**9.5%**	**35.8%**	**59.0%**	**73.7%**	**-**
Residential	-	8.1%	37.6%	60.7%	72.3%	-
Commercial	-	5.0%	27.8%	52.5%	70.4%	-
Industrial	-	8.8%	36.0%	59.2%	72.3%	-
Outdoor Stationary	-	29.0%	64.2%	81.6%	87.2%	-
Site electricity savings (TWh)	**-**	**21**	**122**	**217**	**297**	**2,672**
Residential	-	7	51	82	102	1,009
Commercial	-	6	38	73	111	902
Industrial	-	0	3	8	11	88
Outdoor Stationary	-	7	30	54	73	673
Site electricity savings (%)	**-**	**3.3%**	**19.4%**	**33.9%**	**45.8%**	**19.7%**
Residential	-	5.1%	37.3%	56.7%	66.9%	32.5%
Commercial	-	1.9%	11.7%	22.9%	35.0%	13.3%
Industrial	-	0.8%	7.4%	18.3%	29.4%	9.3%
Outdoor Stationary	-	6.2%	23.7%	40.2%	51.7%	25.2%

U.S. DOE Energy Savings Potential of Solid-State Lighting in General Illumination Applications, Jan.2012

Total consumption 4273 TWh

297/4273～7%

Forecast of ratio of LED lighting in Japan

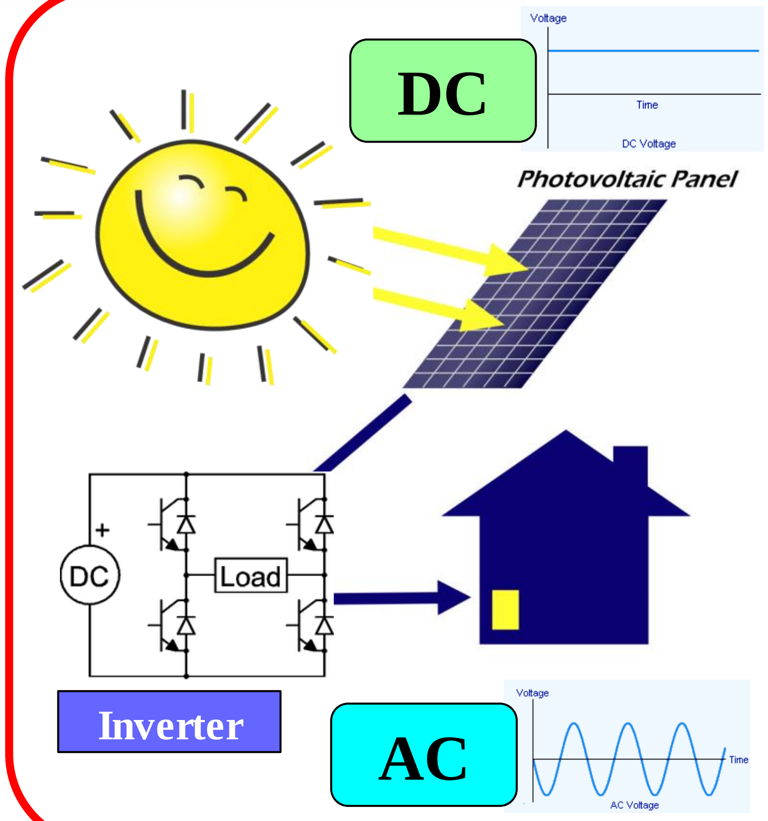


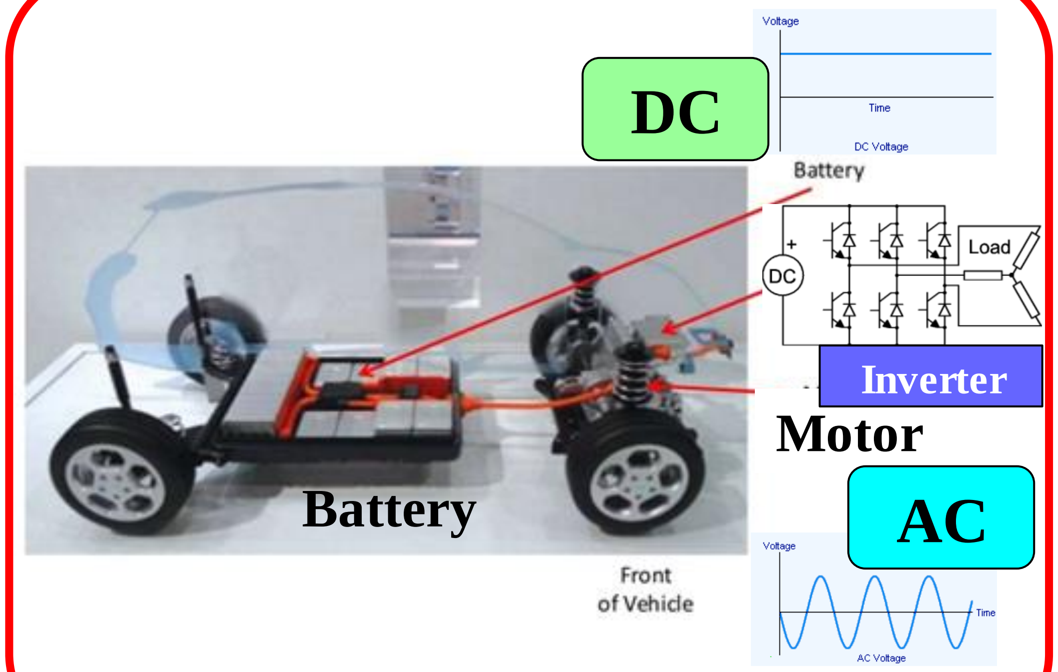
Data from Fuji Chimera Research Institute, Inc.,
2014 LED Related Market Survey

In Japan, we can reduce total electricity consumption by about 7% （=1,000,000,000,000 JP Yen） by 2020.

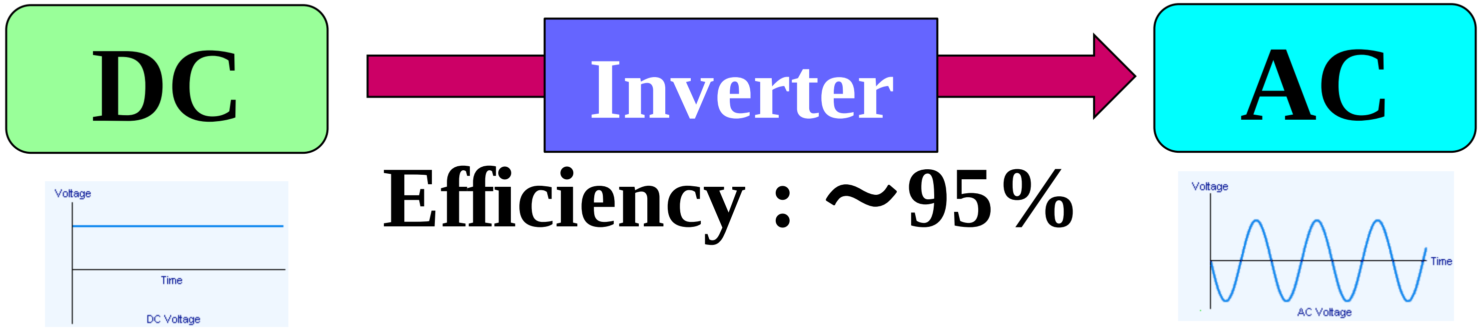
Future Prospects

Energy savings with SiC/GaN power devices



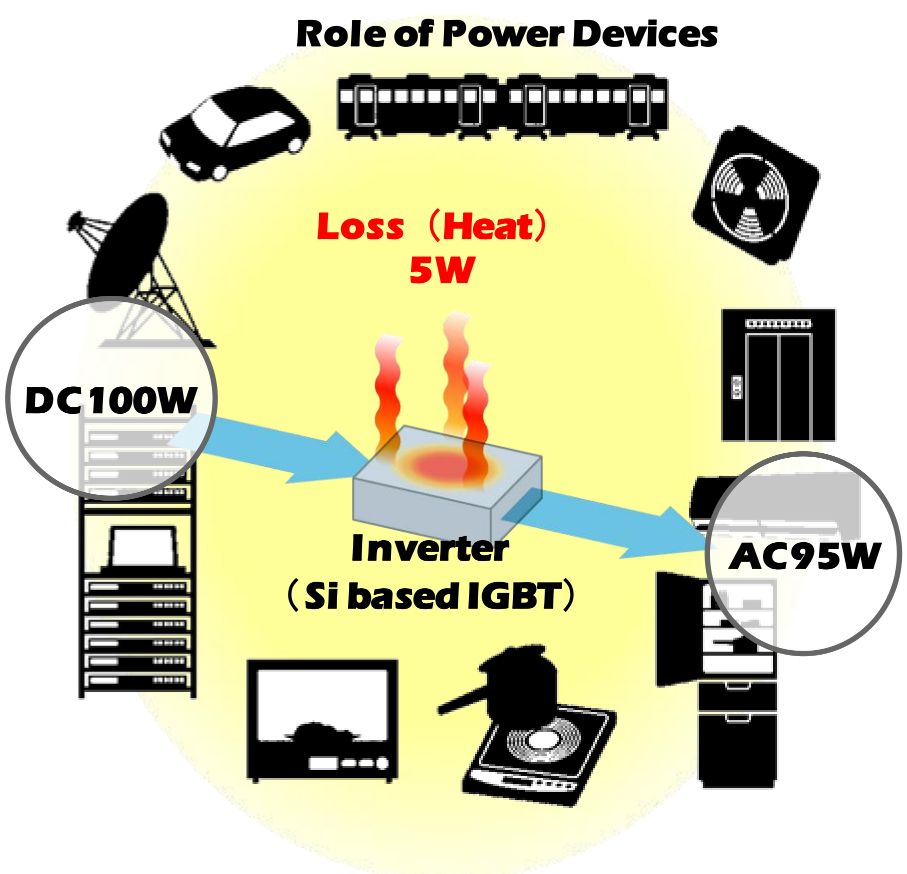


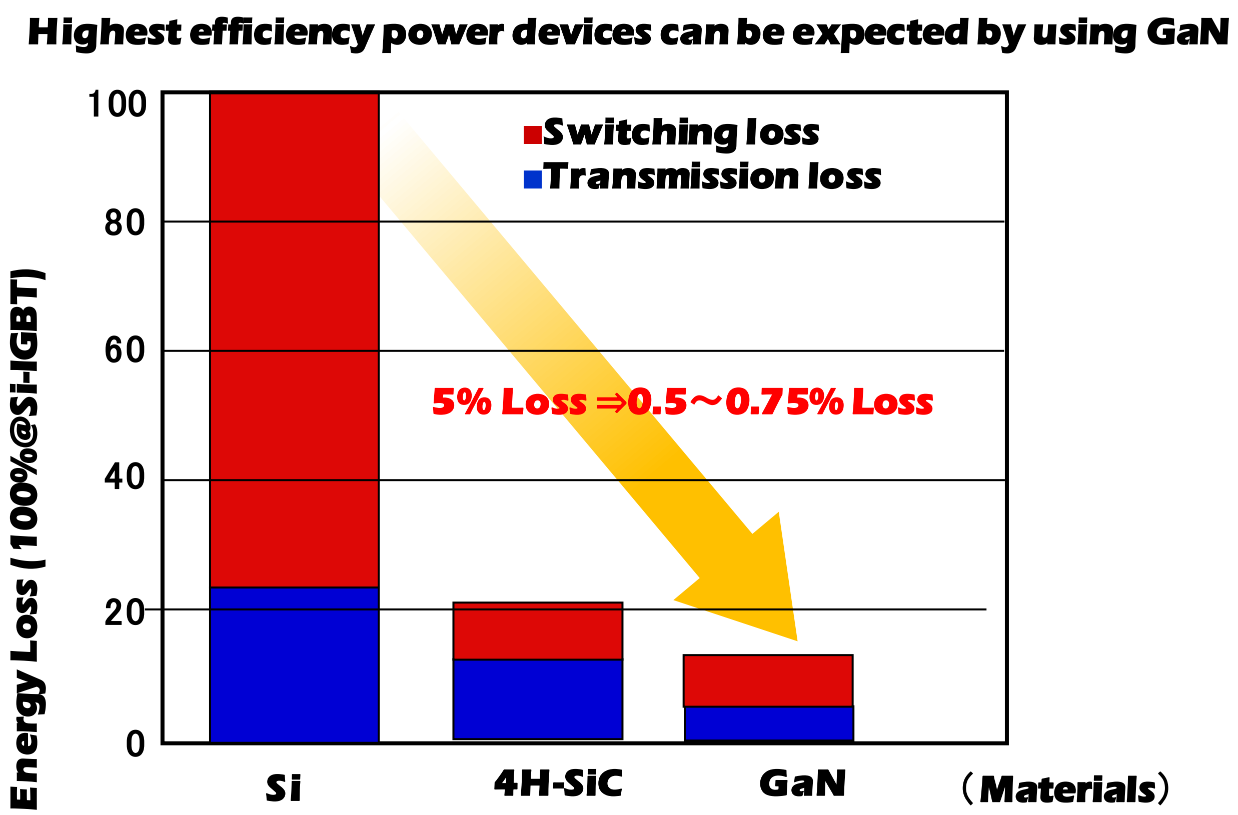
http://www.slideshare.net/gordonjames35728/why-electric-2015



Efficiency : ～95%

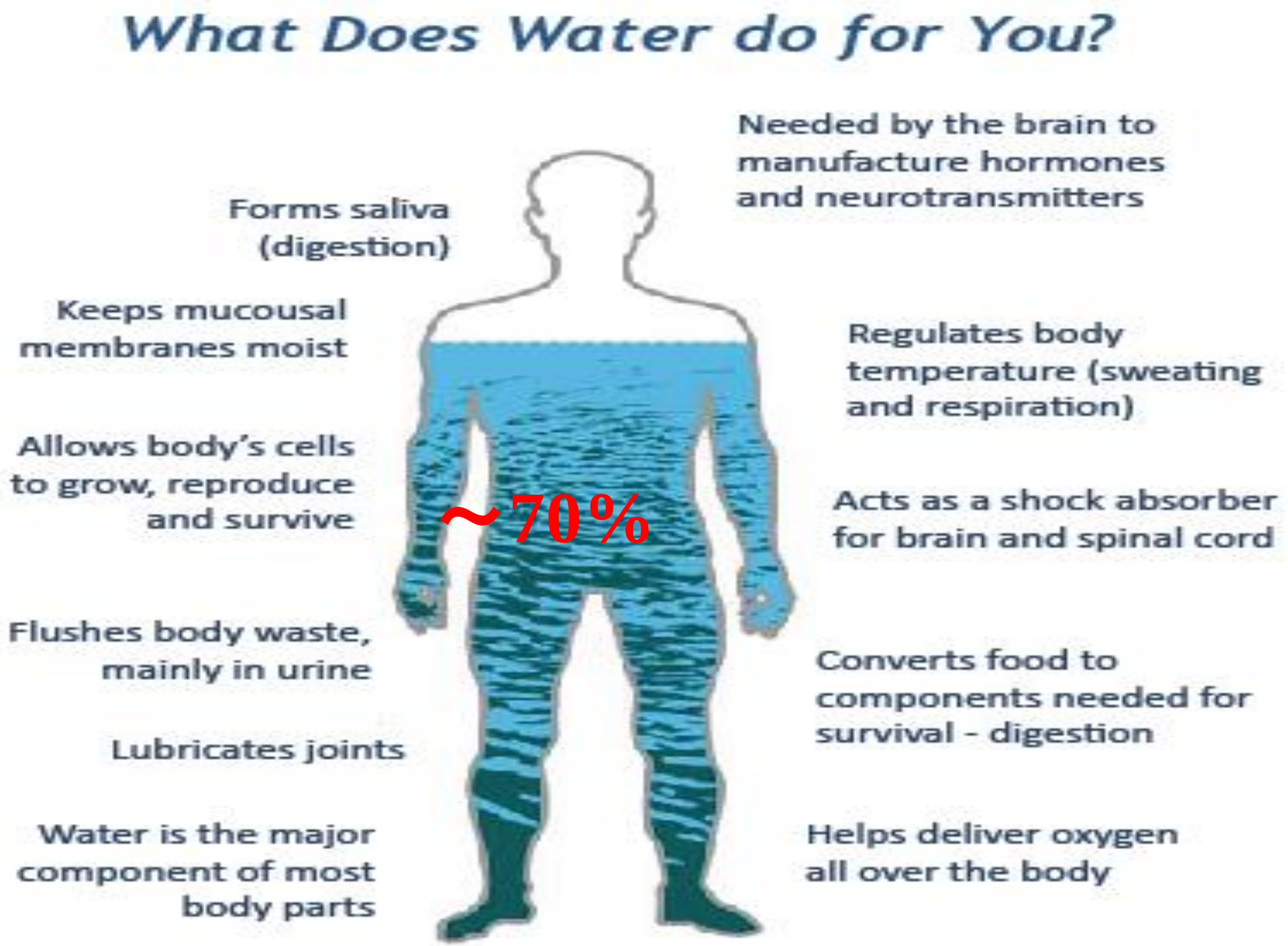
Energy savings with SiC/GaN power devices





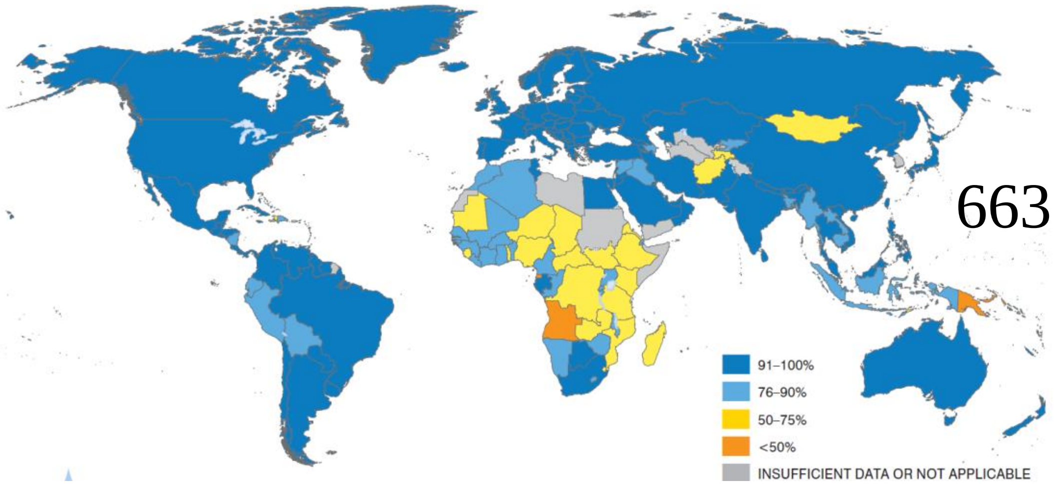
- By replacing Si-based IGBT to SiC/GaN devices, 9.8% of total electricity consumption can be saved.

Water issues



http://water.usgs.gov/edu/propertyyou.html

People who cannot access to safe water



lack access to improved drinking water sources

663 Million people

SUB-SAHARAN AFRICA, 319
SOUTHERN ASIA, 134
EASTERN ASIA, 65
SOUTH-EASTERN ASIA, 61
OTHER REGIONS, 84

Unicef
World Health Organization,
Progress on Drinking Water and Sanitation
2015 Update

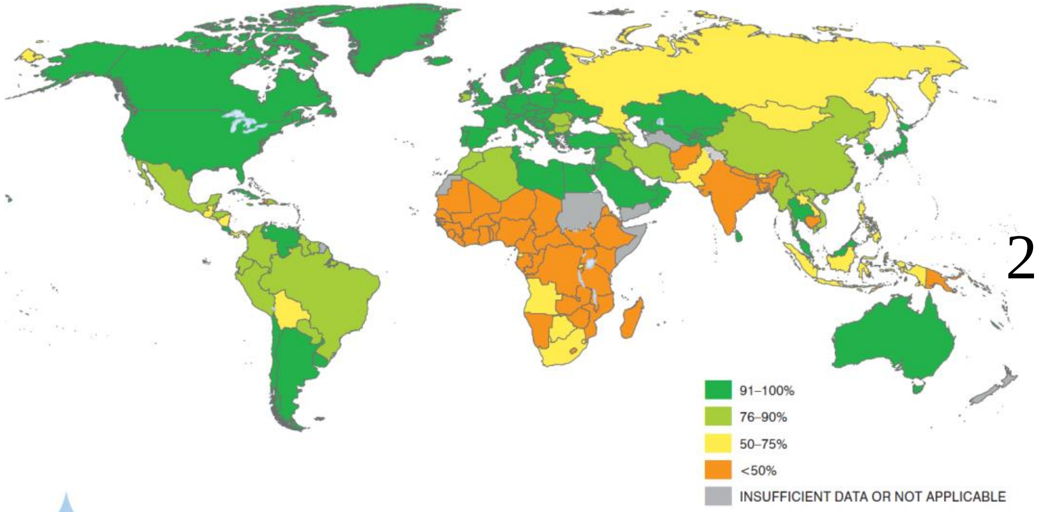


Fig.16 Proportion of the population using improved sanitation facilities in 2015

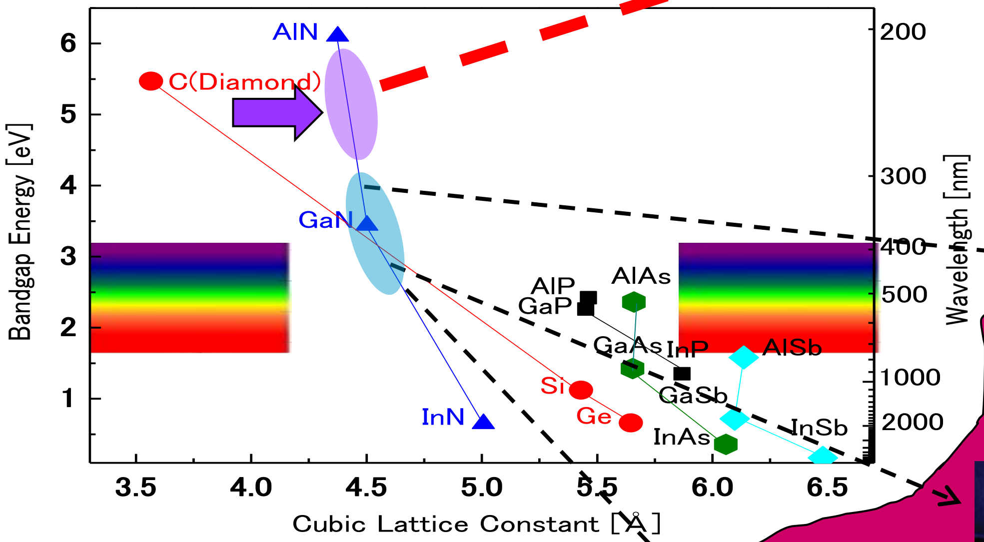
do not use an improved sanitation facility

2.4 Billion people

SOUTHERN ASIA, 953
SUB-SAHARAN AFRICA, 695
EASTERN ASIA, 337
SOUTH-EASTERN ASIA, 176
LATIN AMERICA AND
the CARIBBEAN, 106
OTHER REGIONS, 98

Challenge to DUV region

$$a_{cubic} = \sqrt[3]{\sqrt{3}\times a_w^{\ 2}\times c_w}$$



NIKKISO

http://blogs.unicef.org/2014/03/20/world-water-day-2014-the-forgotten-768-million/

High frequency and high power HEMT

http://www.sei.co.jp/newsletter/2010/09/6a.html

Violet LDs, blue LDs

Blue LEDs, Green LEDs, White LEDs

Colon bacillus

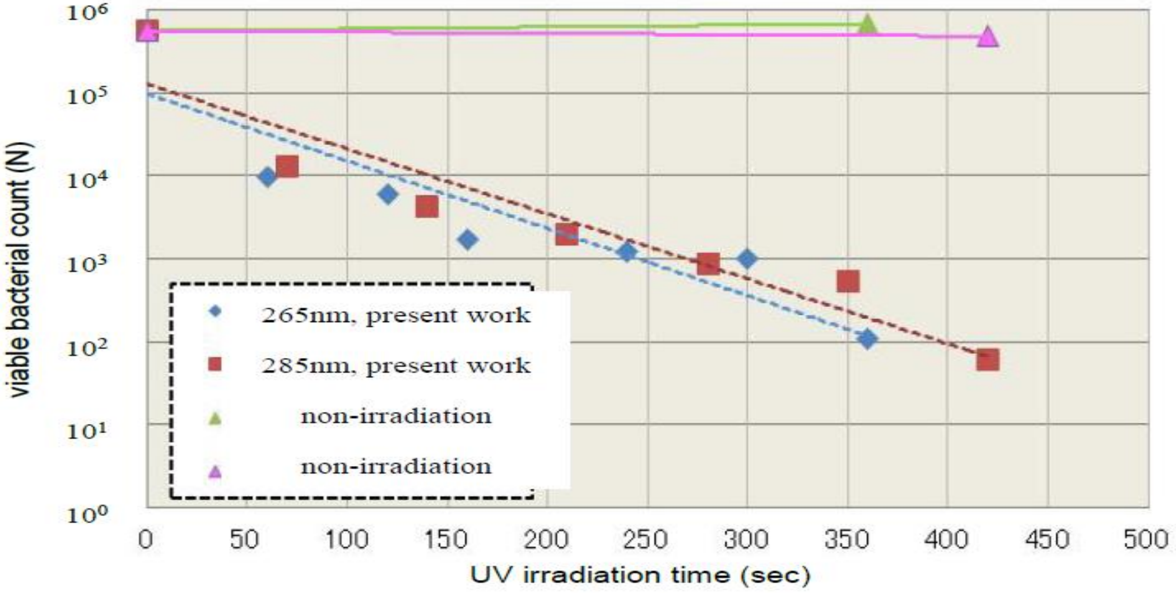
UV-LED Specifications:

(a)Wavelength: 265nm
Forward current: 60mA
Lighting intensity: 1.33mW/cm^2

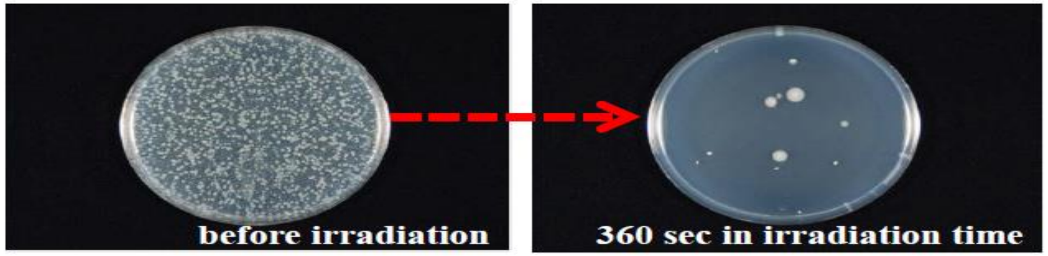
(b)Wavelength: 285nm
Forward current: 60mA
Lighting intensity: 2.41mW/cm^2

Irradiation distance: 10mm

Bacterial
1) Escherichia coli, NBRC3972

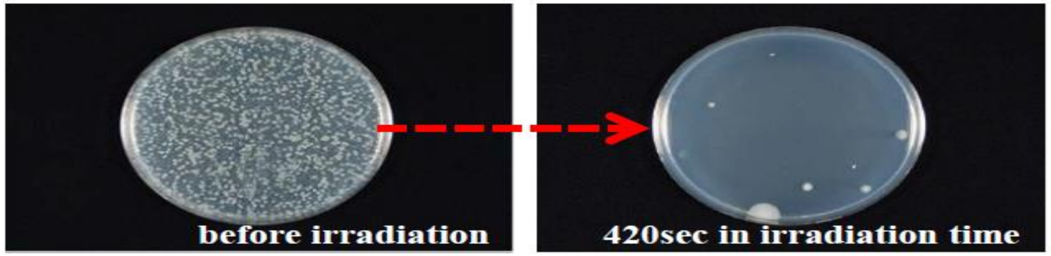


(a) 265nm UV-LED



6 min.

(b) 285nm UV-LED



7 min.

How to Create Innovation Ecosystems ?

- **Little and often fills the purse.**
- **Pertnership between industry, government and academia is essential for contribution to society.**