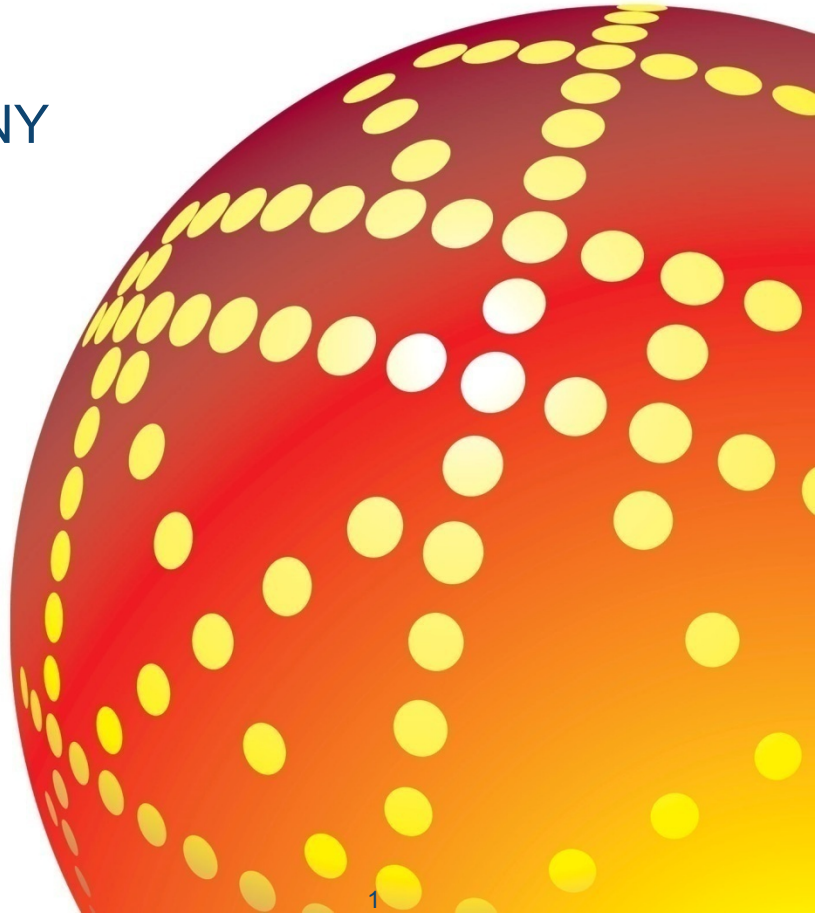
# Leveraging semiconductor technology for the benefit of society

**Fernando Guarín Ph.D.**
**IEEE Fellow**
Global Foundries Reliability, East Fishkill NY

GLOBALFOUNDRIES

September 23, 2016



# There are many challenges in the world

## Electricity

170 billion kWh wasted yearly due to insufficient power usage information.

## 4.2 billion lost hours and 2.9 billion gallons of gas

Annual impact of congested roadways in the U.S. alone.

## 1.1 billion

The number of people that do not have access to safe water according to The World Bank.

## 25%

Proportion of worldwide CO2 emissions created by power generation, the largest man-made source.

## 50% water loss

Impact to many municipalities' water supply through leaky infrastructure.

# The Water Problem

## 6x

Increase in global water usage since the 1900s; twice the rate of human population growth.

## 1.1 billion

The number of people that do not have access to safe water according to The World Bank.

## 9B/50%?

The number of people expected to live on earth by 2050/the expected increase required in agricultural output to feed them….

## 2/3

Two thirds of the world's population is projected to face water scarcity by 2025, according to the United Nations..

## 45%

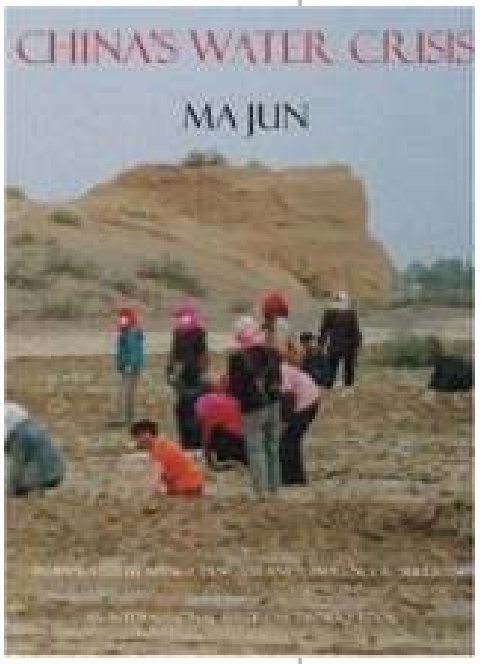
Up to 45% of treated water is lost due to leaks in an aging water infrastructure around the world.

# Relevant Water Facts

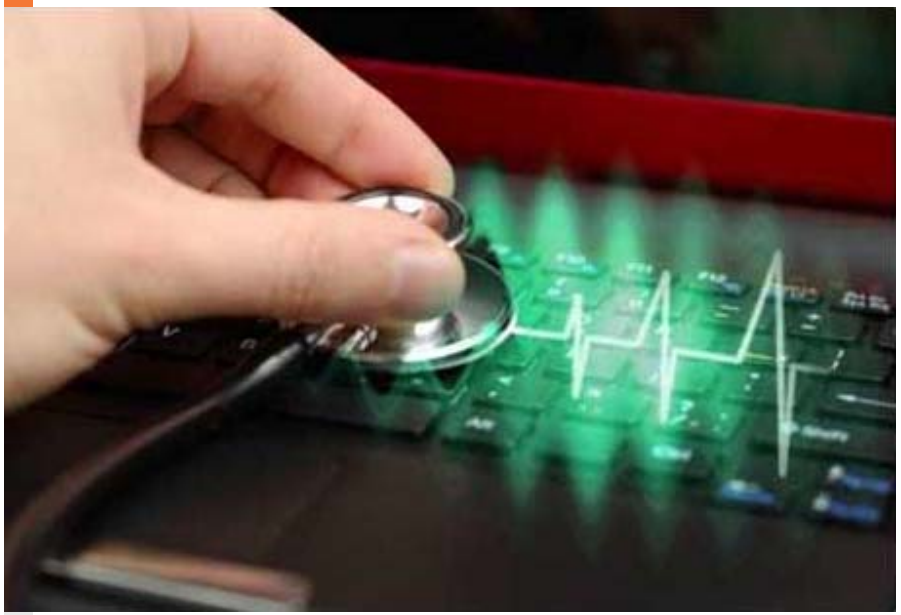
- 2 billion tons of waste water — including fertilizer run-off, sewage and industrial waste — is being discharged daily. That waste fuels the spread of disease and damages ecosystems.
- "Sick Water" — the 2010 report from the U.N. Environment Program — said that 3.7 percent of all deaths are attributed to water-related diseases, translating into millions of deaths.
- More people die from polluted water every year than from all forms of violence, including war.
- More than half of the world's hospital beds are filled by people suffering from water-related illnesses
- It takes 3 liters of water to produce one liter of bottled water, and that bottled water in the U.S. requires the consumption of some 17 million barrels of oil yearly.
- Dead zones in oceans are oxygen-deprived areas caused by pollution they are spreading worldwide
- Current world population is 7 billion and will increase to over 9 billion by 2050.
- We need to be more intelligent about how we use water and how we manage waste, including wastewaters.

# Water Issues:  Is Water the new Oil?





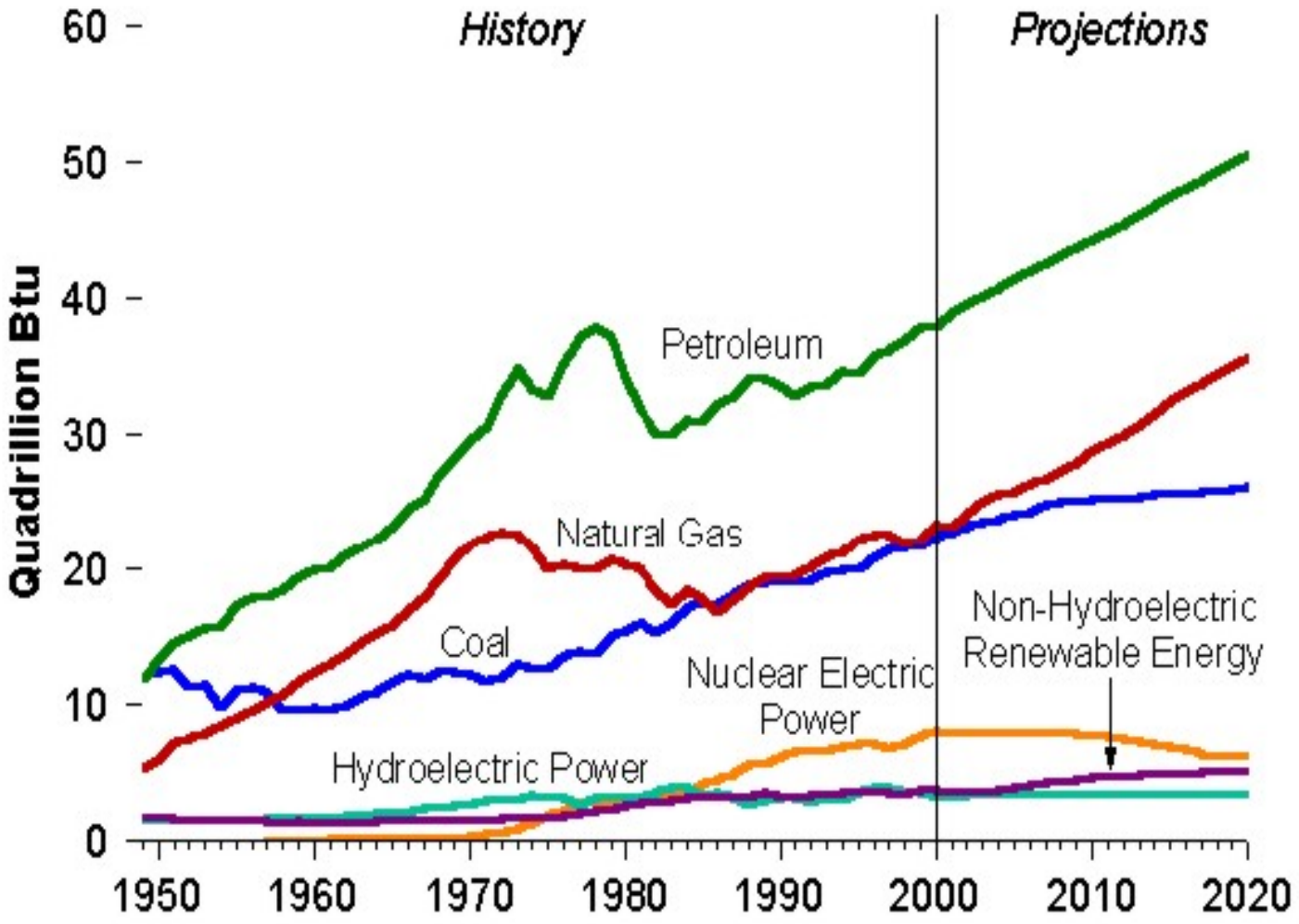
# Healthcare



- Technology is enabling giant leaps in medicine (Imaging, monitoring, drug delivery, diagnosis (Watson)
- $475-$750 Billion
  - Range of estimated U.S. healthcare spending each year on administrative and clinical waste, fraud and abuse and other waste.[1]
- 1.5 Million
  - Errors in the way medications are prescribed, delivered and taken harm 1.5 million people in the U.S. every year.[2]

In 1900, 13% of world population lived in cities.
In 2007, for the first time in history, the majority of the world's population—3.3 billion people—lived in cities.
By 2050, city dwellers are expected to make up 70% of Earth's total population, or 6.4 billion people.

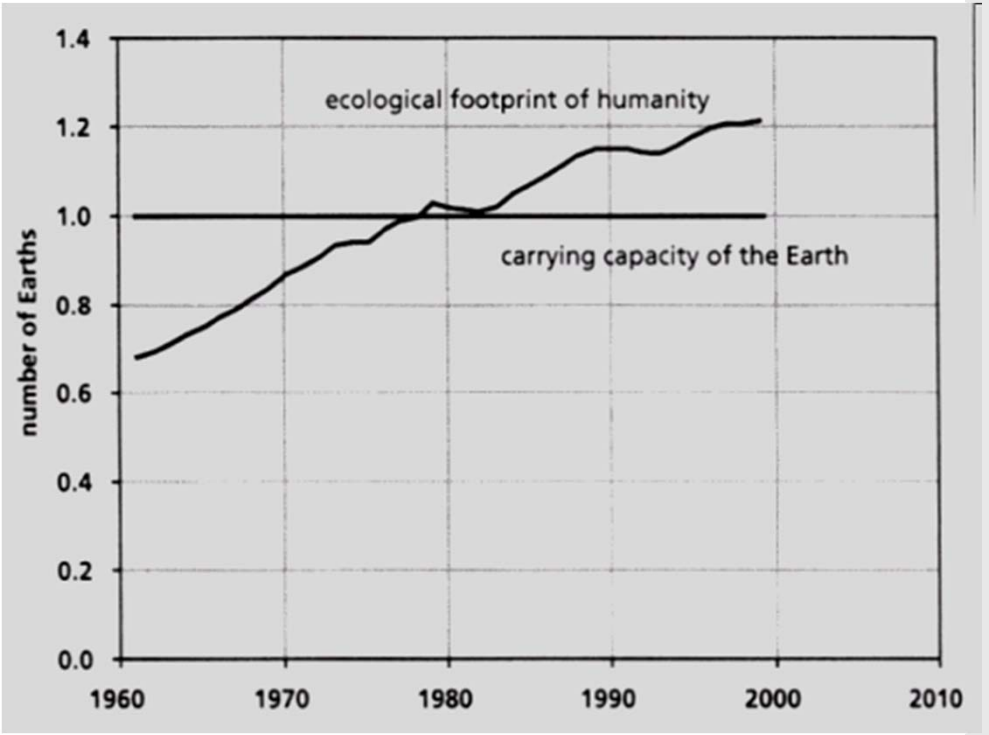
The U.S. gets 94 percent of its energy from nonrenewable sources and 6 percent from renewable energy sources.




http://www.eia.doe.gov/emeu/aer/eh/frame.html

# Earth can no longer sustain human footprint

- Several revisions were provided
  - 1972
  - 1993
  - 2004
- All showed that much more effort will be required to manage the earth's resources than in the past
- Potential for the planet to run out of key resources in 21st century




Carrying Capacity of the Earth

Source: M. Wackernagel et al

# One of our best options is to leverage technology

- Sensors
- Processors
- Instrumentation
  - Internet of Things
  - Optimize Renewable Energies

**Semiconductor Technology**

# Can just one person make a difference?

## Let me introduce you to Prof. Jayant Baliga NCSU

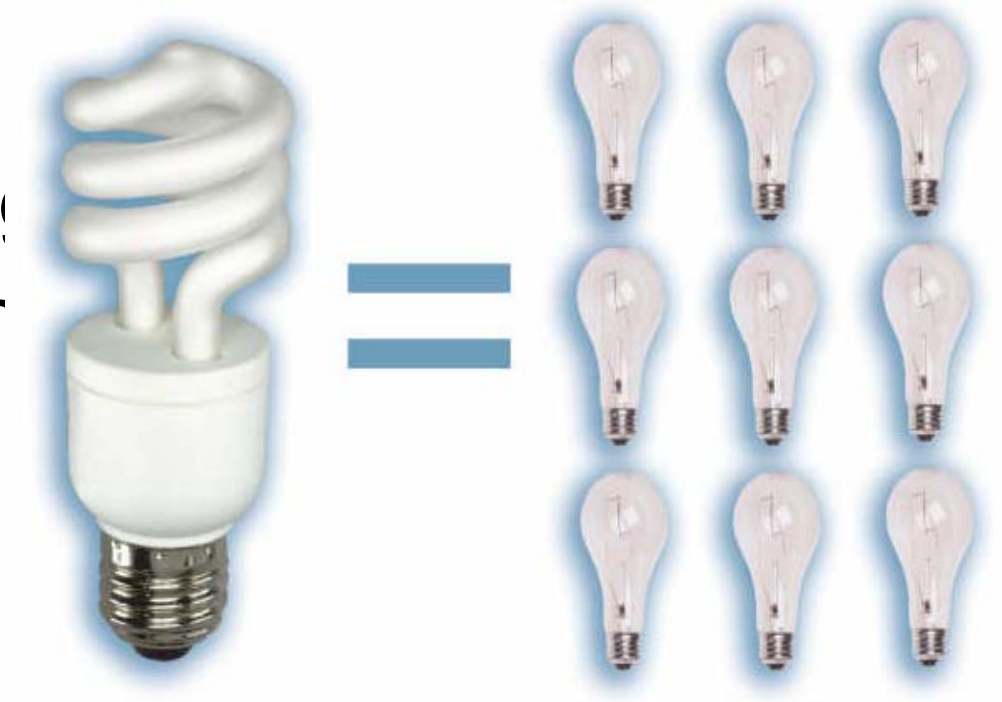
## In 1980 while working at G.E he perfected the IGBT (Insulated Gate Bipolar Transistor)

# Evolution in our ability to switch power.

• Early 1900s era of mechanical switches and relays achieve speeds in the range of seconds.
•1950 bipolar transistor bulky for power applications and had relatively low current gain
•1970 replaced by power MOSFETs
(MOS transistors) can achieve rates that are nine orders of magnitude faster (billions of switching events /second), but can be achieved only for very small current loads.
•**Insulated-Gate Bipolar Transistor or IGBT** For higher power applications -→ increase of six orders of magnitude (millions of switching events /second)
•Perfected in around 1980 by J. Baliga
used as an electronic switch in just about all of today's modern appliances and many more advanced systems, from lighting, electric washers, air conditioners(anything with an electric motor) to electric cars, airplanes, bullet trains and medical applications.

# Improved Efficiency

- **Lighting**
  - CFL
  - 75% less ener
  - Less cooling ir summer
  - $50 per bulb




Courtesy J. Baliga

B. Jayant Baliga

# Social Impact

| IGBT Enabled Application | Cumulative Gasoline or Energy Savings | | Cumulative Carbon Dioxide Emission Reduction | |
|---|---|---|---|---|
| | U.S. | World | U.S. | World |
| Electronic Ignition System | 318 B gallons | 1477 B gallons | 6.16 T Pounds | 28.66 T Pounds |
| Adjustable Speed Motor Drive | 25,170 TWh | 56,910 TWh | 34.25T Pounds | 62.61 T Pounds |
| Compact Fluorescent Lamp | 1,550 TWh | 16,120 TWh | 2.09 T Pounds | 17.74 T Pounds |
| TOTAL | | | 42.5 T Pounds | 109 T Pounds |


**The elimination of 1.5 Trillion Gallons of Gasoline and 73,000 Terra-Watt-Hours of Electricity has reduced $CO_2$ emissions by 109 Trillion Pounds**

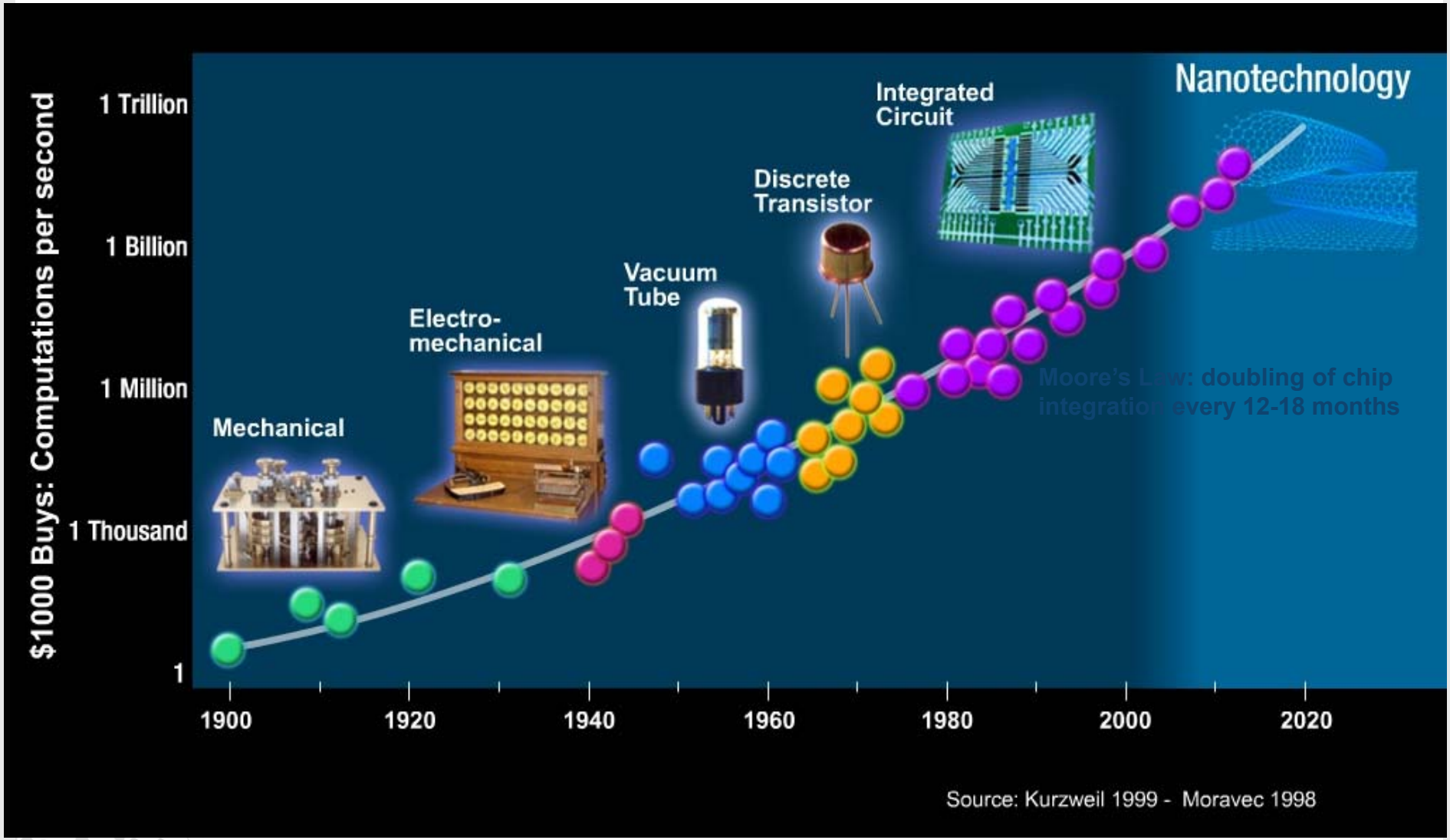
**Total Global Carbon Dioxide Emissions per Year = 8000 Pounds per person x 7 Billion = 56 Trillion Pounds**

**World-Wide Utilities did not have to construct 1366 1-GW Coal-Fired Power Plants saving $ 4 Trillion**

**By not consuming 1.5 Trillion gallons of Gasoline and 73,000 TWh of Electricity, World-Wide Consumers have saved $ 23.7 Trillion**

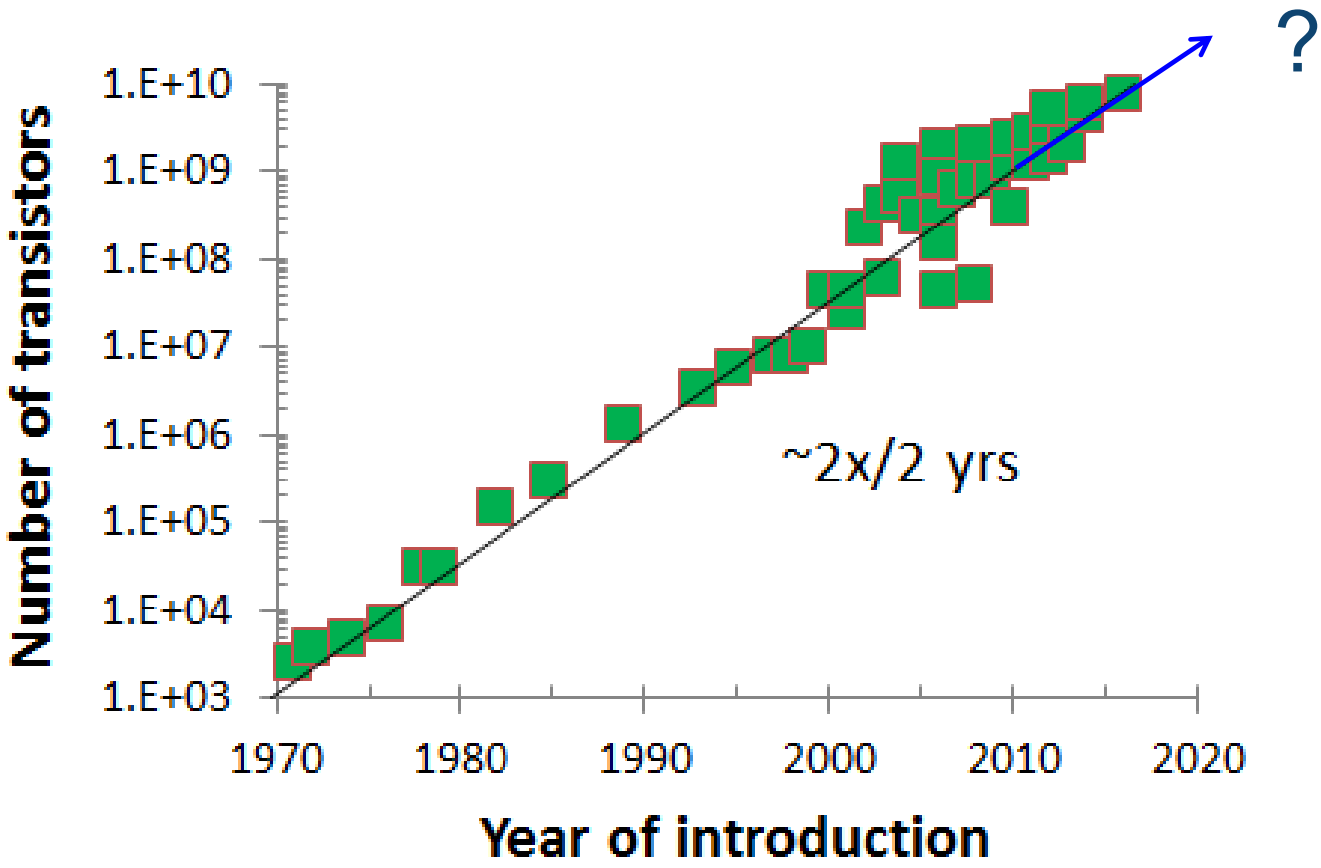
Courtesy J. Baliga

# Accelerating Advances in Technology



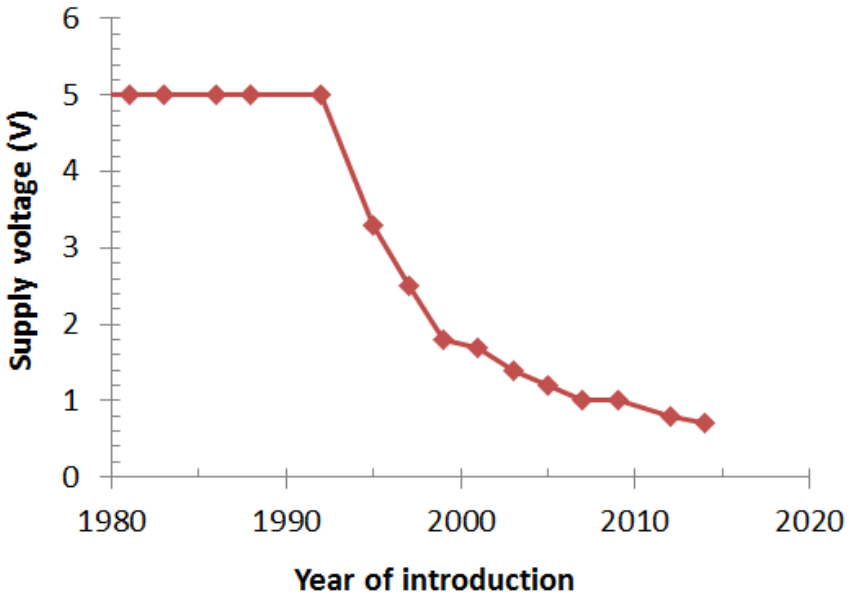
# Moore's Law

How far can Si continue to support Moore's Law?

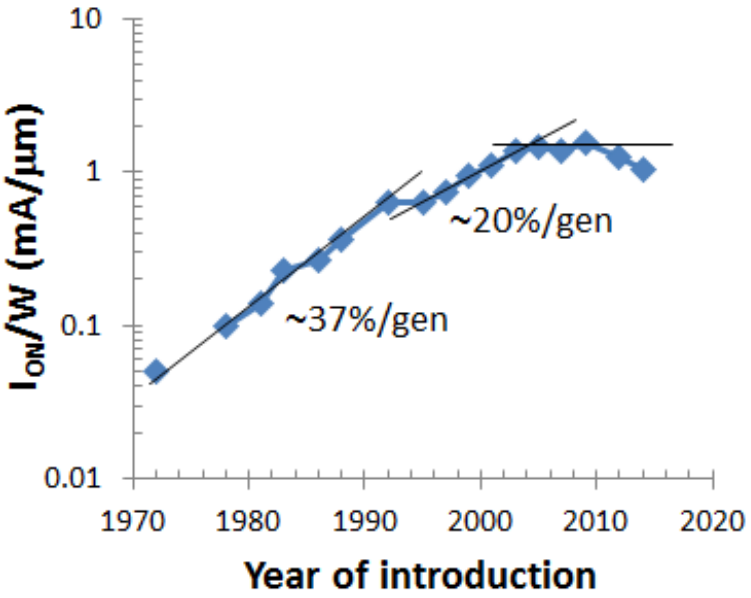


# Transistor scaling
## Voltage scaling and Performance issues

Supply voltage:




Transistor current density:

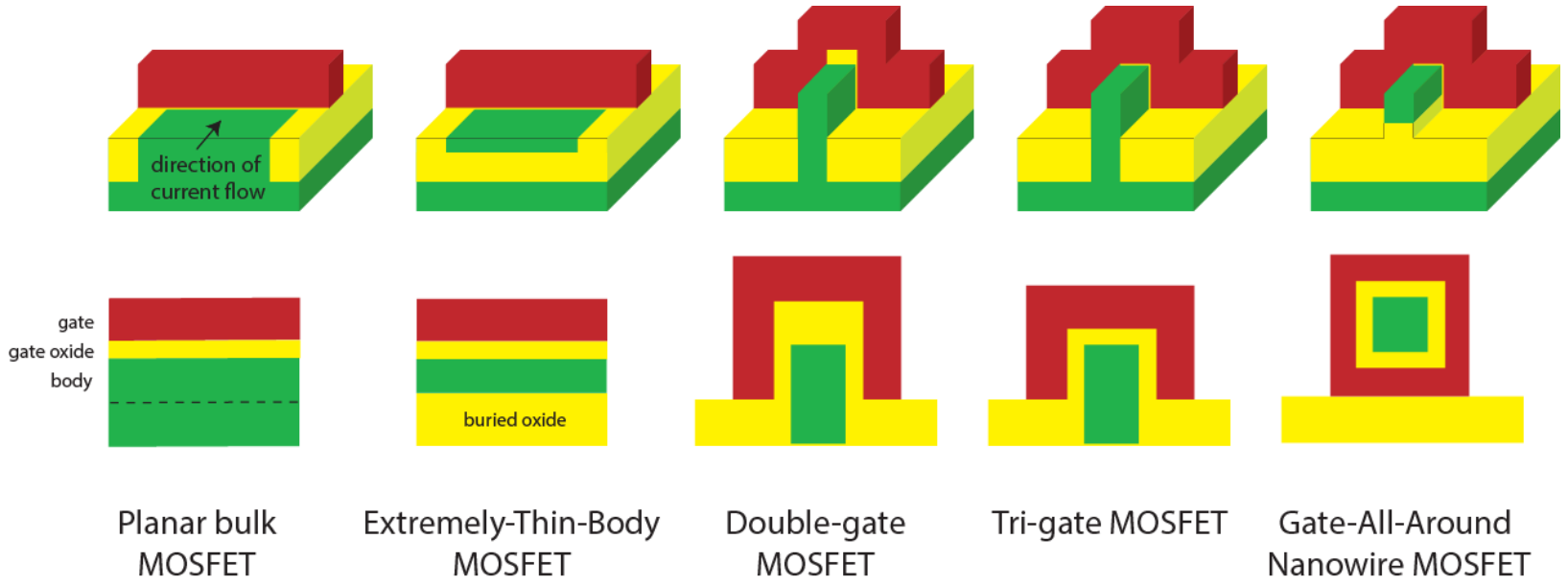



Goals:

- Reduce footprint with moderate short-channel effects
- High performance at low voltage

# Structures and Materials

1. New device structures with improved scalability:

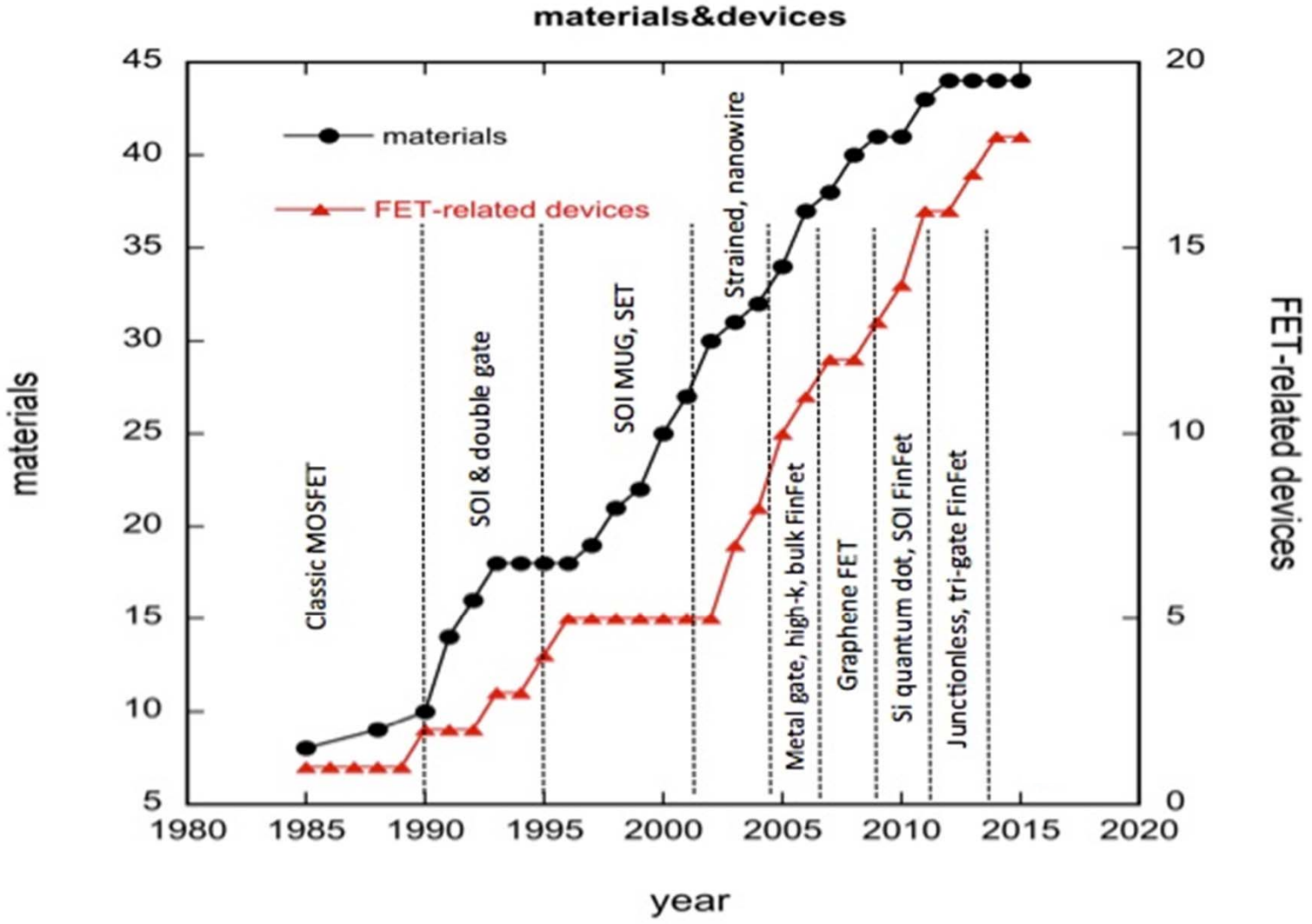



2. New materials with improved transport characteristics:

n-channel: Si → Strained Si → SiGe

p-channel: Si → Strained Si → SiGe → Ge

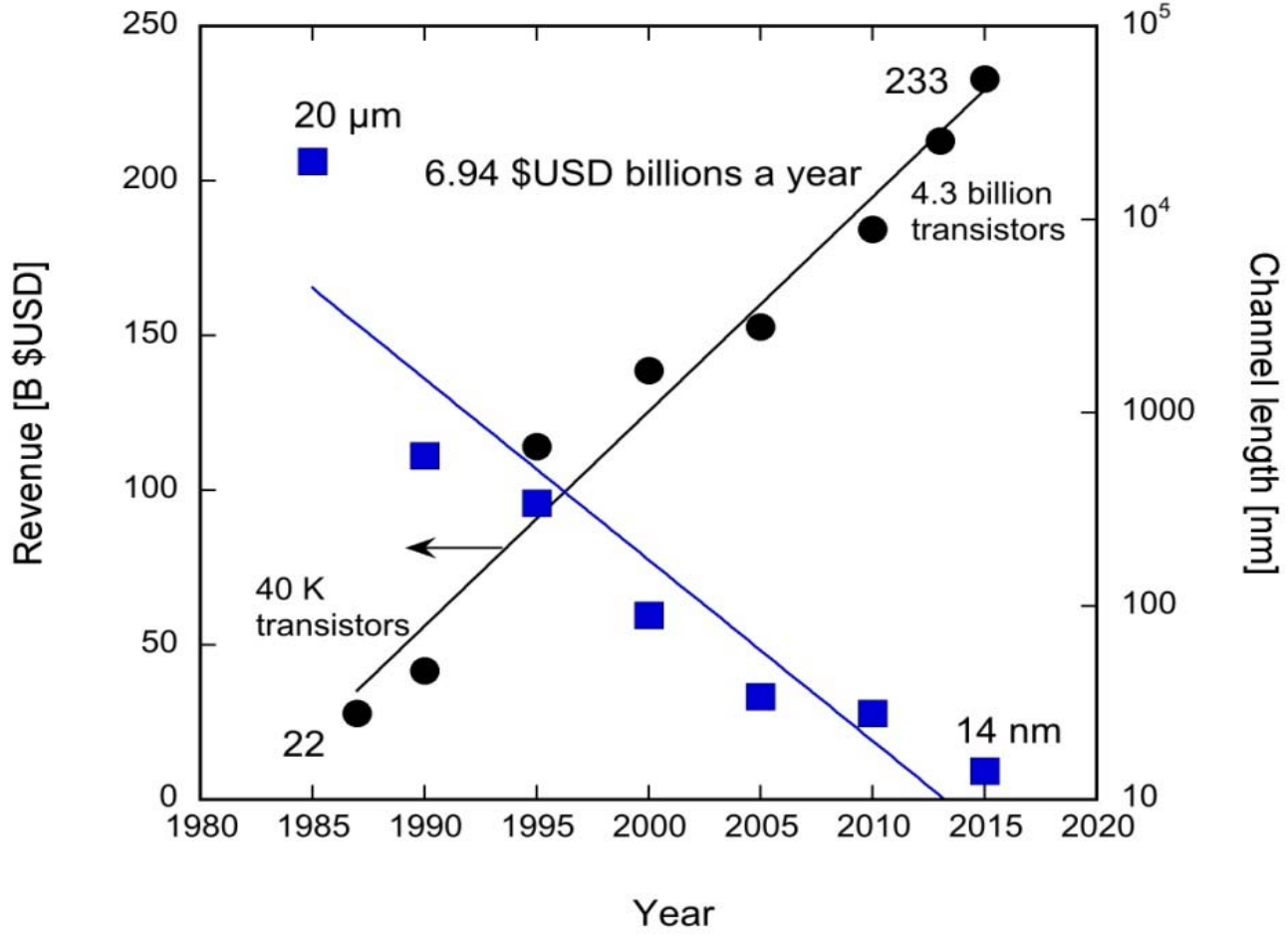
# Introduction of materials and different FET-related device structures




Innovation → keeps scaling going

E. Gutierrez, et.al. "Nano-Scaled Semiconductor Devices, IET 2016

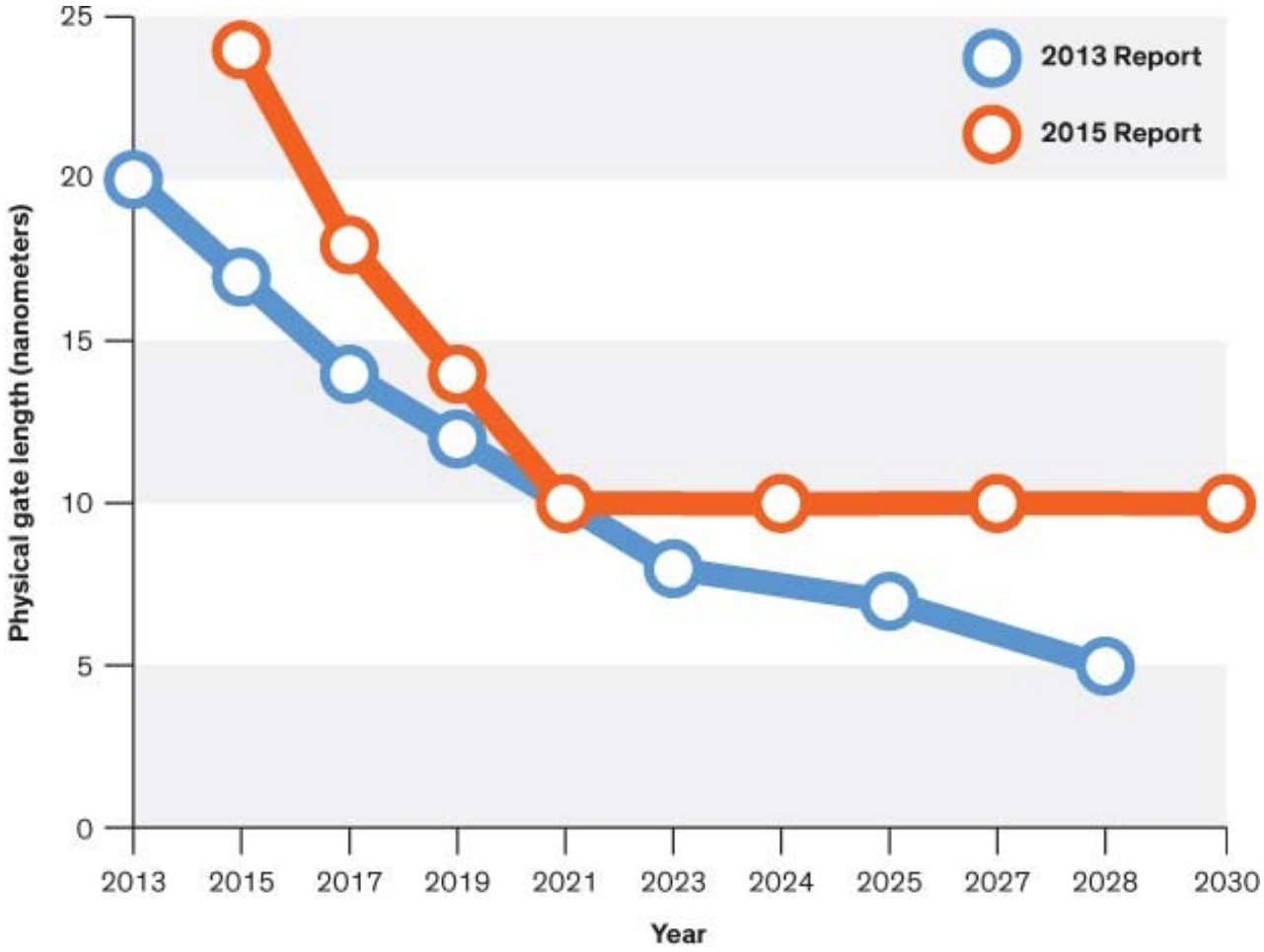
# Revenue vs Channel length




Business and device dimension evolution of MOSFET technology from 1985 to 2015.

E. Gutierrez, et.al. "Nano-Scaled Semiconductor Devices, IET 2016

# ITRS July 2016 - http://spectrum.ieee.org/tech-talk/computing/hardware/transistors-will-stop-shrinking-in-2021-moores-law-roadmap-predicts

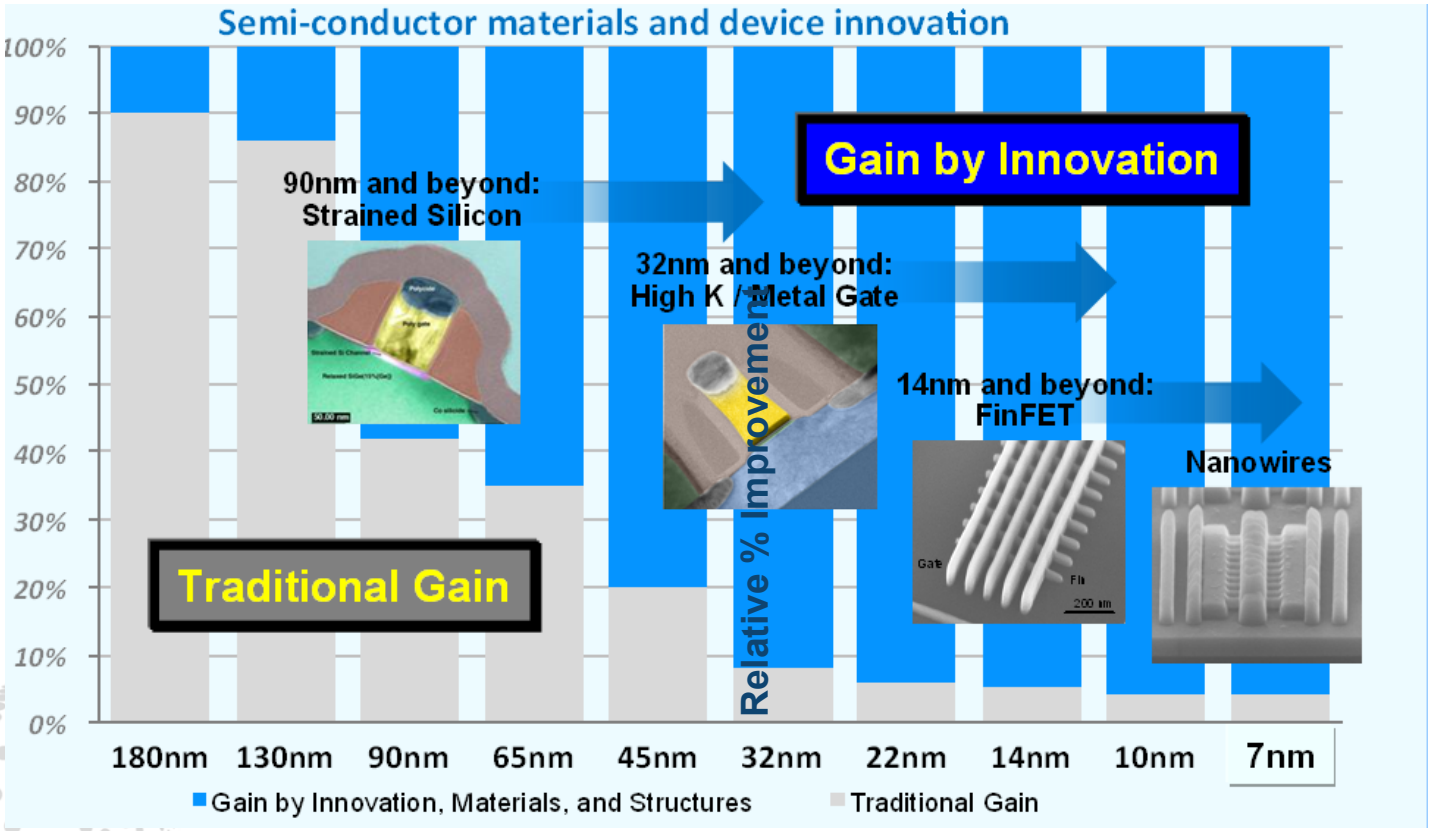



After 10 nm, it is not practical to reduce further: major path is Innovation (gate all around horizontal, vertical, SiGe, Ge, III-V e 3D.)

# Innovation:
# Key to Keep Scaling Going

- **Innovation is critical for solving technology challenges of Nano Silicon Technology**
- **Leadership in innovation through long term investments in fundamental research**
  Cu and High-k technologies required 10+ years of sustained R&D

**Transistor Performance Improvement**




G. Patton

# Future ?

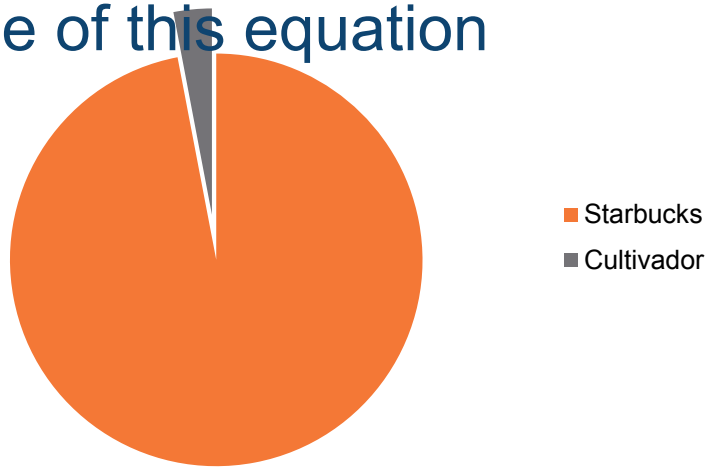
- New device architectures (CNT /nanowires / quantum dots)
- New Materials (III-V, graphene)
- Packaging innovations
- Intersection with other sciences
  - biology / medicine / neuromorphic computing
- Disruptive breakthroughs?

# Economics 101 (Value Added)

-The price of a cup of coffee at Starbucks in New York is about $ 3

•-Out of the $3 97% goes to “knowledge economy

- •Genetic engineering
- •Transport and distribution
- •Marketing / branding
- •Advertising
- •Supply Chain management
- •- Only three percent goes to the coffee producer
- •- Latin America is on the wrong side of this equation



# Economic Perspective

- In 1900 Latin America accounted for 8% of world trade
- In 2016, 116 years later we represent exactly the same.
- Why?
  - We are not diversifying our economy
  - We are exporting raw materials
    (same as when we were European colonies)
  - Lack of governmental policies / incentives
  - Region of great potential  (will always be)
- 83 percent of Latin America's exports are raw materials and derivatives
- For 2016 Latin American economic growth is near zero.

# Economy (2)

- As long as Latin America does not diversify its exports, it will always be stuck in the same situation (at the mercy of commodity prices)
- Latin America sells products that are worth less and less
- In the global economy products with high added value worth more and more.
- The solution is to add value to the products Latin America exports
  invent new products
- In 2015 USA registered 159000 patents, Japan 56000, South Korea 18000, Germany 17000, China 8700, Israel 3600, India 3000
- Latin America combined how many?
  836 (Brazil 362, Mexico 222, Colombia 25, Bolivia 1)
- Percent of GDP spent on R&D
  - Israel 4.2, South Korea 4.1, Japan 3.5, Germany 3
  - Brazil 1.2, Argentina 0.6, Mexico 0.5, Chile 0.4, Colombia 0.2

# Change is needed

- Education, education, education
- Best Latin American University  ranked 500 / 600
  - There is no lack of talent
  - Every major technology leader has top contributors from Latin America
- Building “technological parks” is not the best approach
- Must create a culture of innovation
  - Culture:  the values, norms, unconscious messages, and subtle behaviors of leaders and people
  - Create: Strategies,  business models,  structure, processes, technologies, tools, and reward systems
  - Coordinate all of the above and establish measurements (what is measured improves,  but it is important to track the right metrics)
  - Don’t be afraid of failure ( the only sure way to not make mistakes is not to do anything)

# Where to Innovate?

- Wind, Wave and Hydro Power
- Photovoltaics  Active Solar Heating
- Municipal and General Wastes
- Landfill Gas  / Geothermal
- Agricultural and Forestry Wastes
- Energy Crops  Fuel Cells

# Renewable Energy

## WIND

Wind turbines produce some of the lowest-priced renewable energy. In places with enough wind, it's already cost-competitive without subsidies, and in some regions it's even cheaper than fossil fuels.

Average global growth (per year) of wind energy since 2000

**24%**

Source: International Energy Agency

## BIOMASS

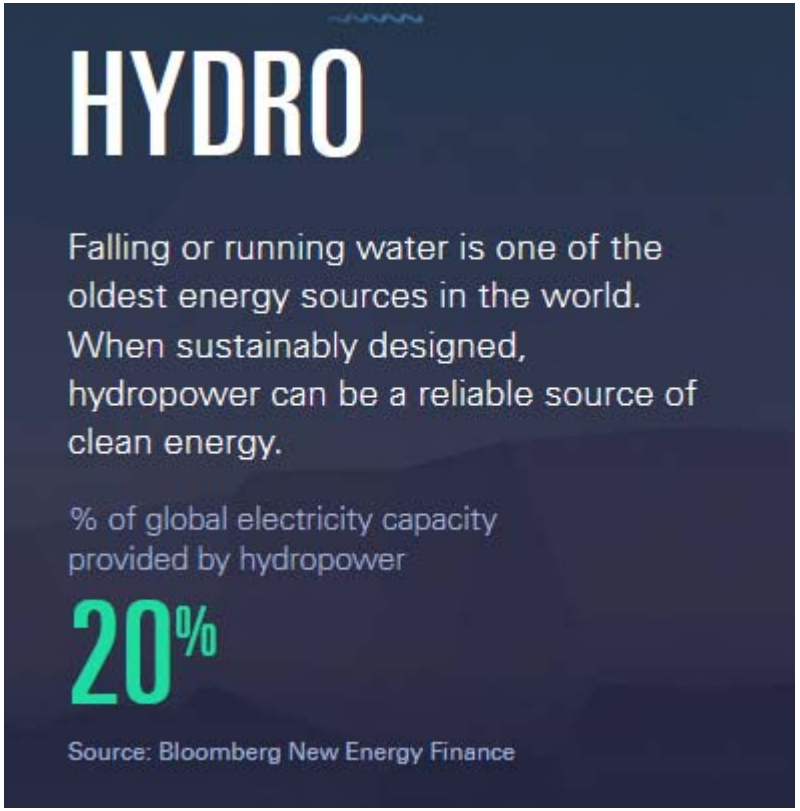
Sustainable biomass energy is derived from living or recently living organisms —everything from forest residue to algae and switchgrass.

% of Brazil's industrial sector powered by biomass

**21%**

Source: International Energy Agency

# Renewable Energy

# Renewable Energy


# So what can each of us do?

# Special Interest Group on Humanitarian Technology

SIGHT is network of IEEE volunteers around the globe that partner with underserved communities and local organizations to leverage technology for sustainable development.

# What is IEEE SIGHT?

## Vision

Underserved communities around the world are able to benefit from technology as they seek sustainable solutions to development challenges.

## Mission

The Special Interest Group on Humanitarian Technology (SIGHT) program is a network of IEEE volunteers around the globe that partner with underserved communities and local organizations to leverage technology for sustainable development.

# What is IEEE SIGHT?

## Values

- SIGHT focuses on sustainable solutions that make a long-term difference in the lives of people
- SIGHT operates through local volunteers and partners working with local communities
- For SIGHT, success is only achieved through partnerships, starting with the community and extending to government organizations, NGOs, schools, hospitals, companies, and others
- For SIGHT and its volunteers to be both effective and sustainable, continuous training and education is essential

# What is a SIGHT Group?

A group of at least 6 IEEE members (*additional IEEE and non-IEEE volunteers are welcome*) who come together to

(1) learn about sustainable development,

(2) build relationships with local underserved communities and,

(3) implement projects that leverage technology to tackle key problem within the community.

Photo: Artisanal Fishers SIGHT, India

# Types of SIGHT Groups

## **Professional** SIGHT Groups

- Sponsored by a society, section, council or region
- Engage in long-term projects with the community

## **University** SIGHT Groups

- Sponsored by a student branch
- Require a faculty lead
- Engage in a “feet on the ground” project with the community

## Imagine

What could happen if ½ million engineers around the world applied their skills to help local underserved communities?

# Gracias
# Thank You

# Impact of Technology to Society

Energy (reliability and impact on the environment)
Environmental issues (Climate change, green technologies, and sustainable design )

Economic Issues
Health and healthcare technologies
Information Technology
Social Issues: Social interaction, Work (virtual chain) Education, Political, Entertainment ( e-Games), Screen addiction, low attention span, Instant gratification
Privacy and security Issues
Public Policy (related to all of the above mentioned areas)
Safety
Ethics and professional responsibility
Humanitarian engineering

# Final Thoughts

**Technology has changed the way we interact**

the proliferation of technologies have enabled us to overcome the obstacles of time and space (e.g., transportation, the Internet)

these tools can be used to gain an understanding of other cultures, meet people all over the world, maintain and strengthen family/friend relationships, communicate effectively with others, access to education and help people to become more socially adept

Could be argued that technological advances cause people to be distracted, overly stressed, and increasingly isolated.

**Technology can have positive and negative impact on social interactions**