Trends in Nanoelectronics: Microchips and More

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Welcome to NACK's Webinar

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Moderator: Michael Lesiecki

Agenda

- About me and my organization
- What makes the iPad so successful?
  - Semiconductors
  - High Brightness LEDs
  - MEMS or Micro Machines
  - Printed Electronics
- Solar PV
- Lessons learned about high technology

About SEMI

- Global industry association
- ~1800 members
- Established in 1970 to serve
  the semiconductor supply chain
- Today serves members interests in the following industries:
  - Semiconductor
  - Flat Panel Display
  - Photovoltaic/Tech-Energy
  - Nanotechnology
  - MEMS

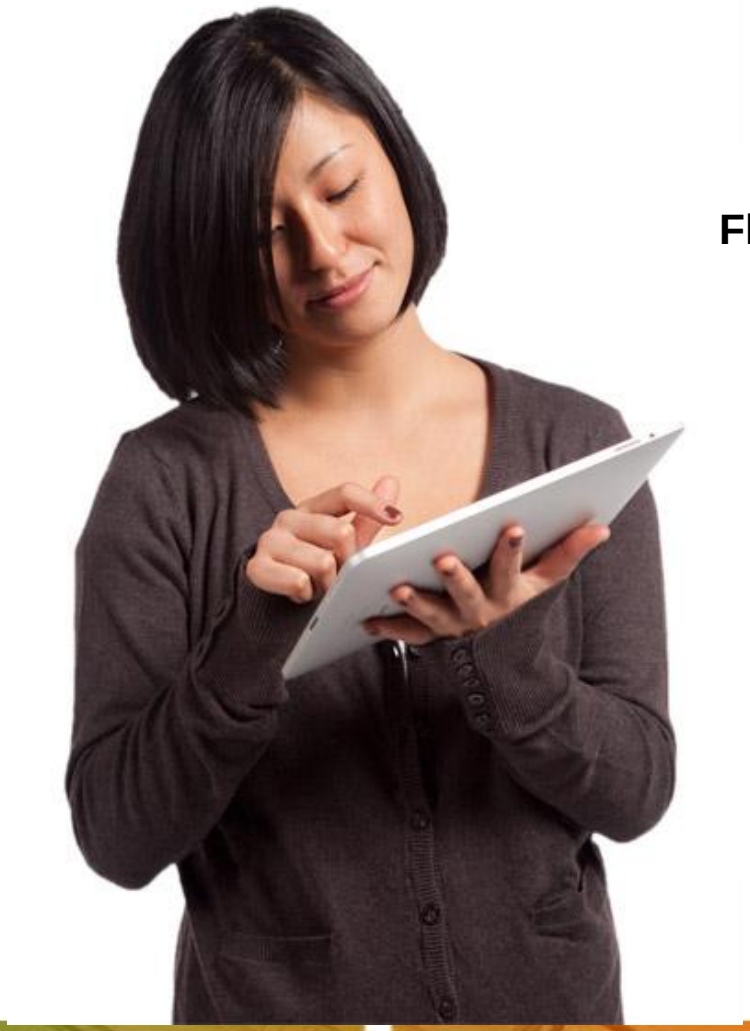
The Next Big Thing?

Innovations in Today's Tablet Computers

Flat Panel Display
High-Definition LCD

MEMS
Accelerometer
Gyroscopes

High-brightness LEDs Backlighting



Flexible Electronics
Multi-touch screen

Semiconductors
Microprocessor

Memory

3G/SIM card

WiFi

Bluetooth

GPS

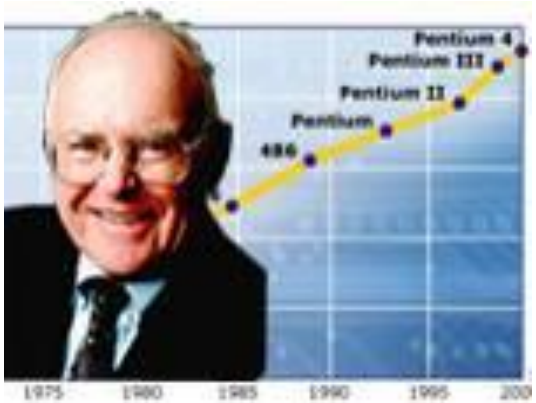
The Electronics Miracle

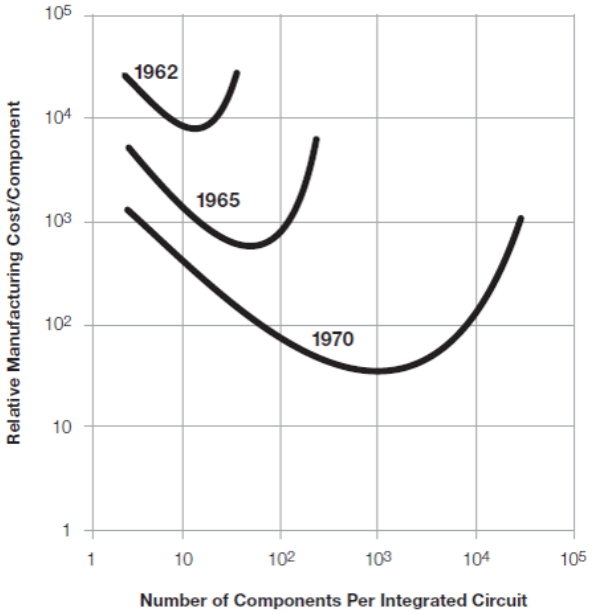
1975
Cost=$1 Billion
Size= House

2011
Cost=$200
Size= Handheld

Moore's Law: An Industry Agreement to Work Together

"Initially, just an observation to predict [that] this was a way to cheap electronics... but the industry made it a self-fulfilling prophesy… **Excerpts from A Conversation with Gordon Moore: Moore's Law Intel 2005**

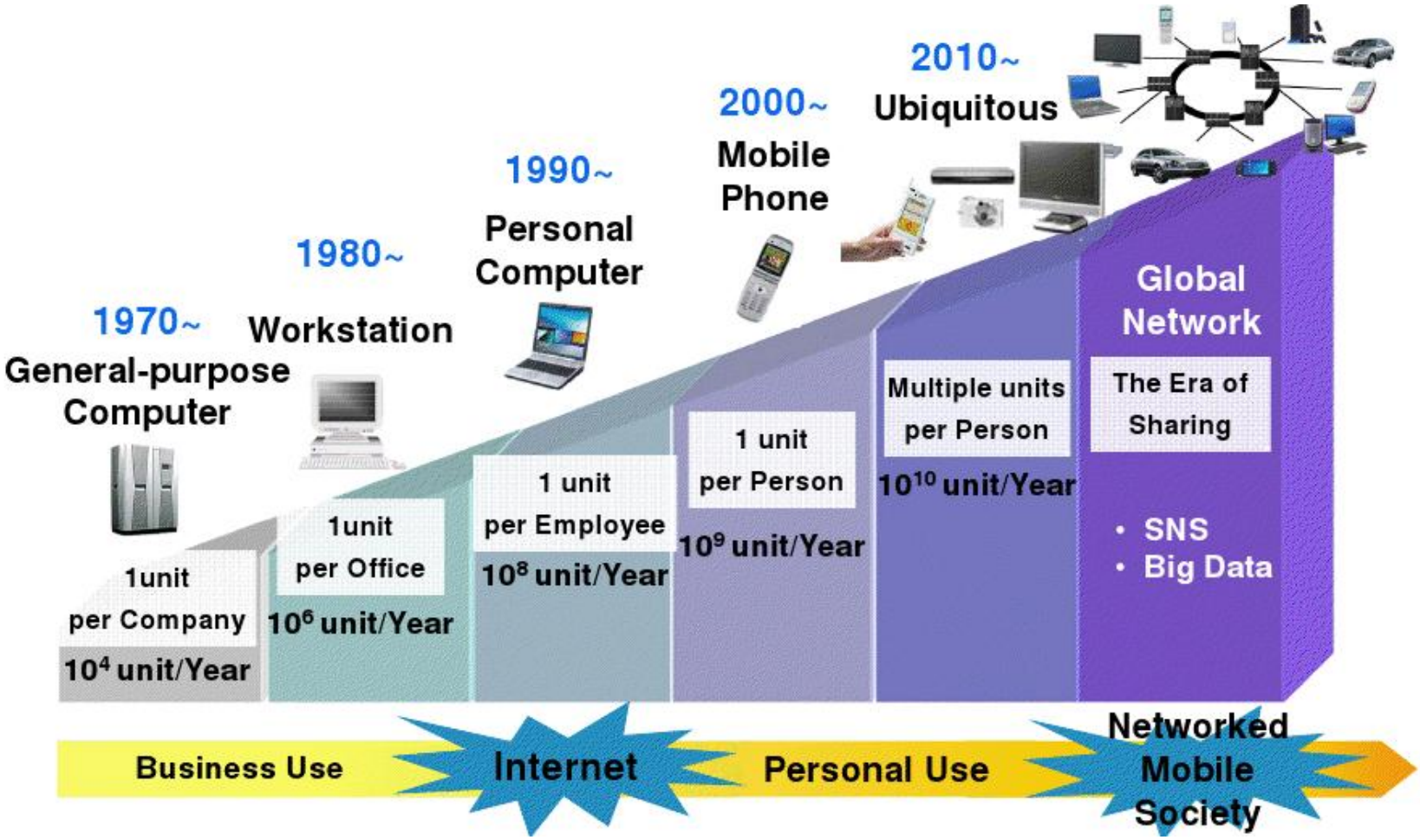




Source: Electronics, Volume 38, Number 8, April 19, 1965

Moore's Law: The long-term trend in which the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years.

Evolution of Chip Demand



The Power of Moore's Law

http://www.youtube.com/watch?v=AWcV-eoJqT8

Evolution of Semiconductor Device Technology

Optical Era → **Materials Era** → **Architecture Era**

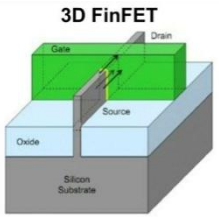
Scaling driven by the advancement of process and materials technology while keeping the same device structure

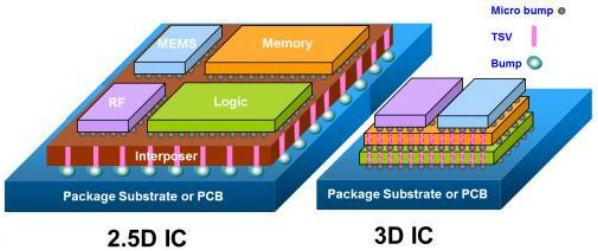
Innovation in device structure

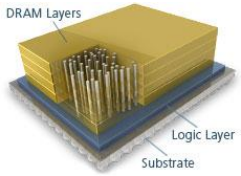
- Shorter Wavelengths
- Illumination Methods
- Phase Shift Masks
- Driven by Optics

- Resists
- Immersion Lithography
- Cu interconnect/Dual Damascene
- Low k dialetrics

- Extended CMOS
- More-than-Moore
- Beyond CMOS
- New Devices



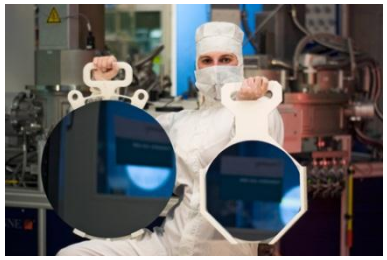


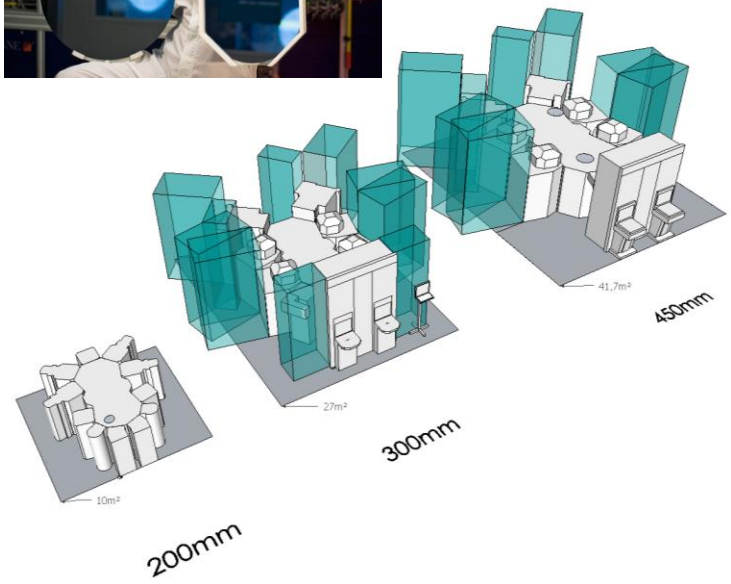


Challenges

EUV Lithography

450 mm Wafer Processing





Semiconductors, MEMS, LEDs, PV, Printed Electronics

- Similarities in
  - Materials
  - Processes
  - Process Integration
  - Equipment
  - Yield
  - Innovation
  - Learning Curve Acceleration

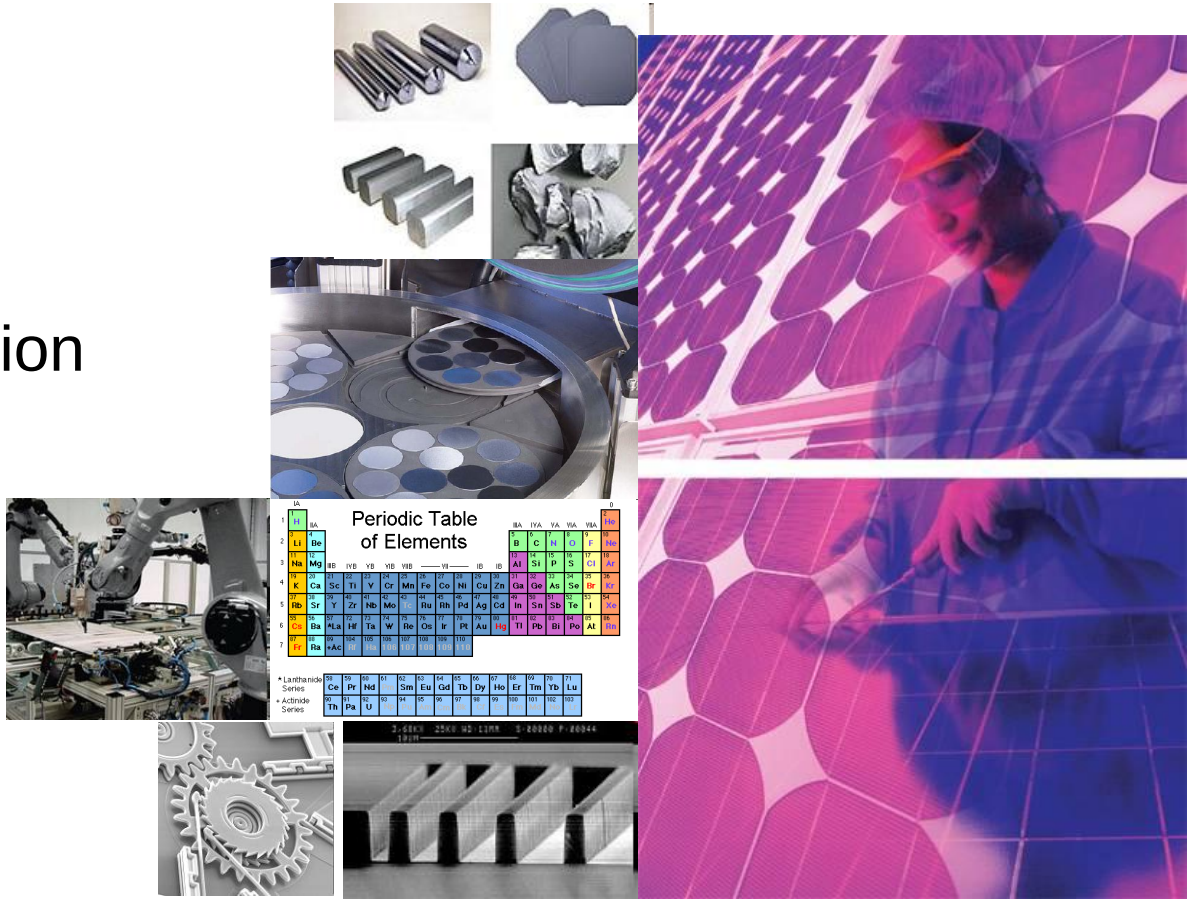
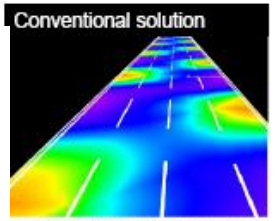
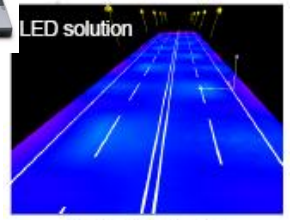


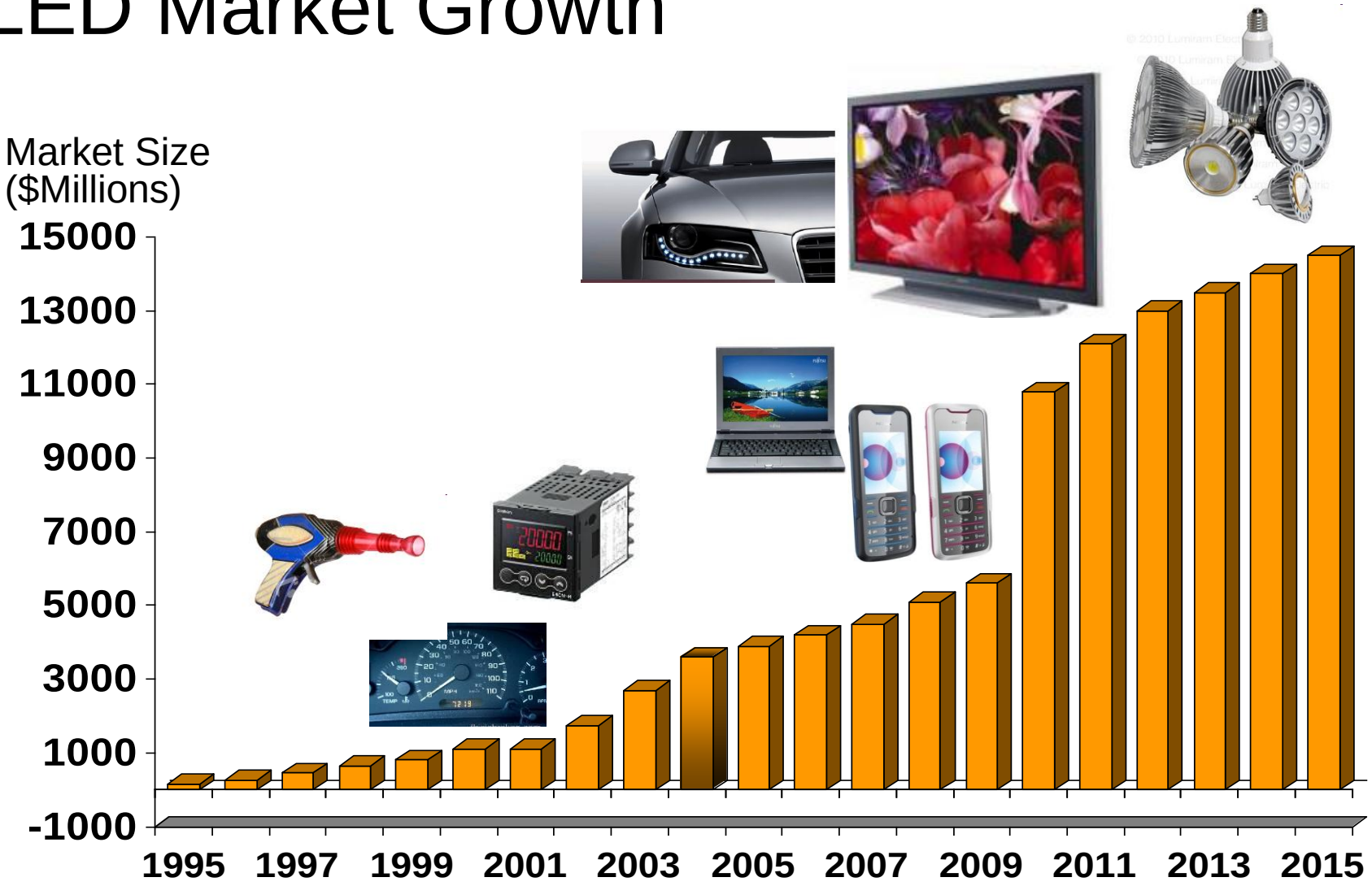
Photo Credit: Hemlock, Sandia Labs, Aixtron, Spire

Light Emitting Diodes (LEDs)





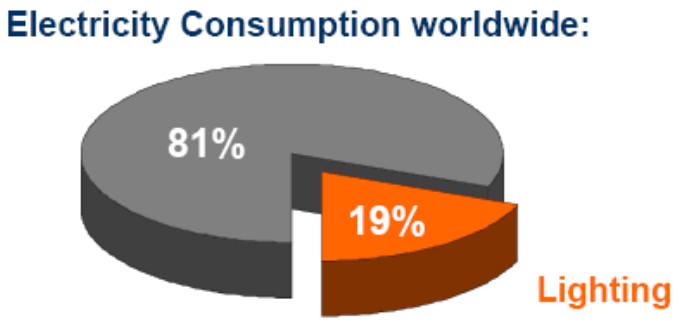
LED Market Growth



Source: Strategies Unlimited, SEMI

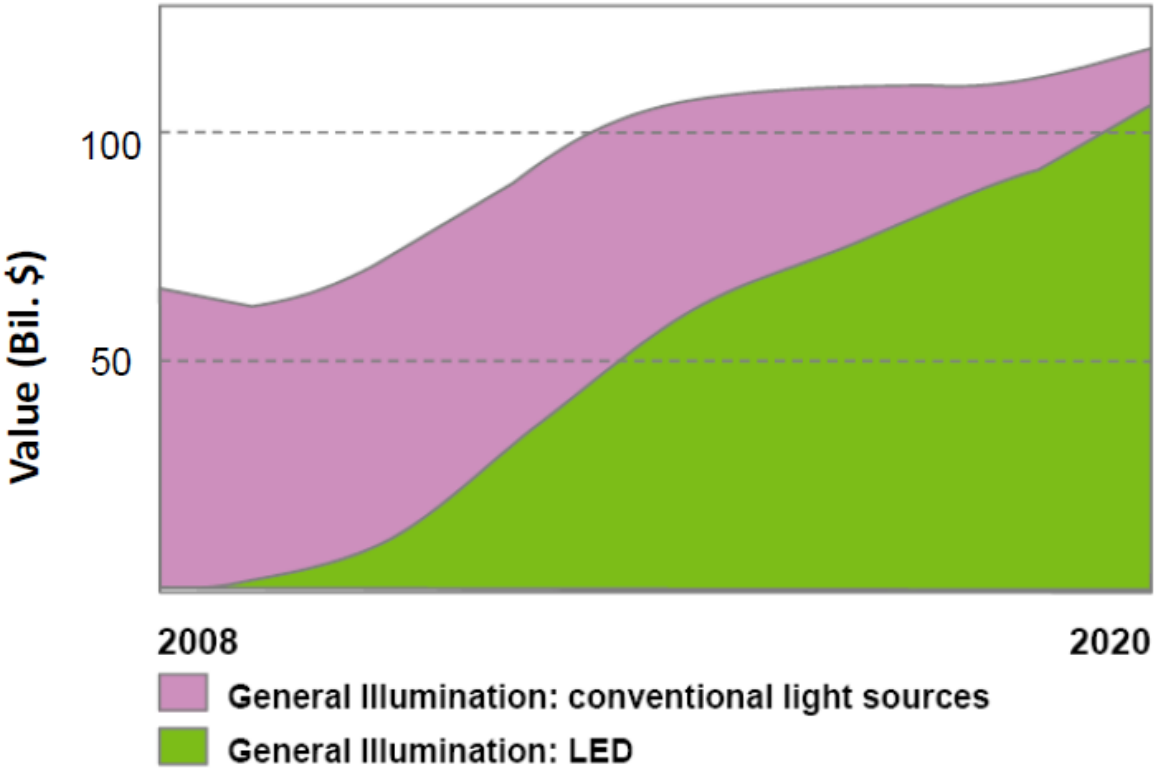
Solid State Lighting (SSL)

- American consumers spend roughly $50B per year on artificial lighting. SSL could save the US about 620 billion kilowatt-hours per year (or approximately 50-70 power plants) by the year 2025.
- “Renewable energy-based solid state lighting is arguably the most important agent of change available to the developing world in the past 100 years!”
  - (LUTW 2008)

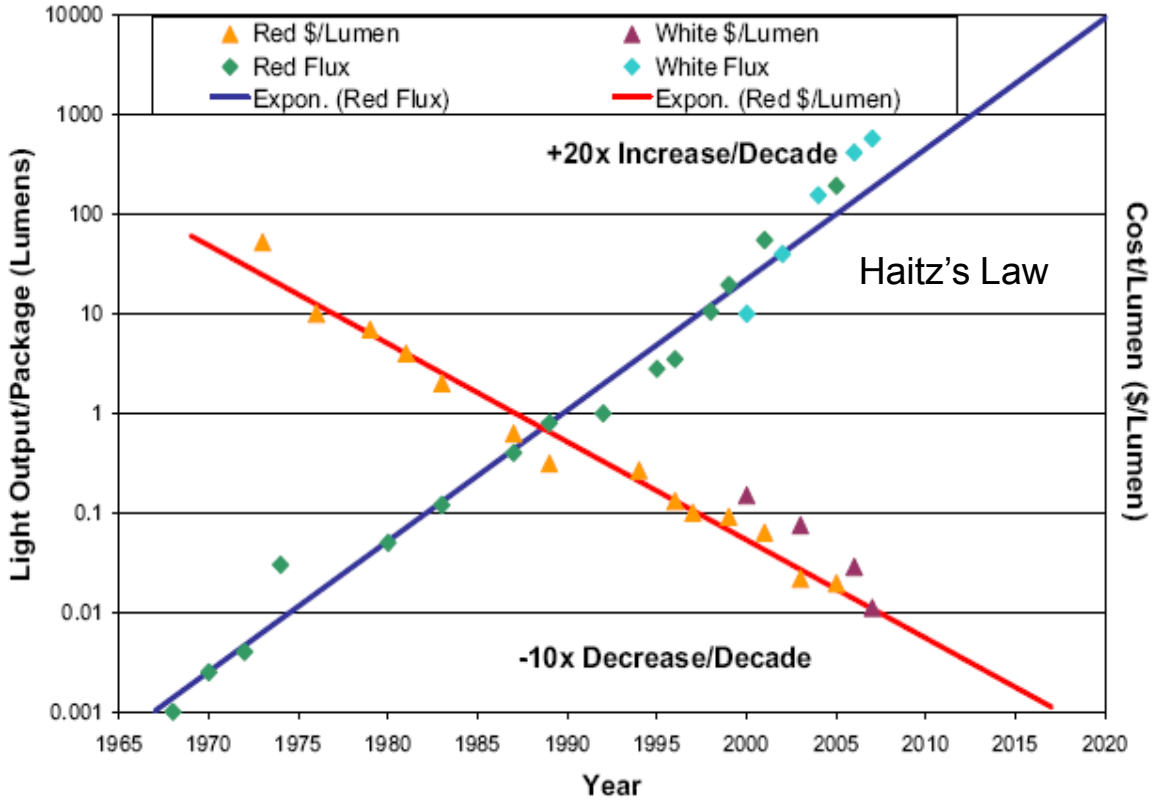


Over 1/3 of the electricity for lighting could realistically be saved: nearly 900 billion kWh or 450 million tons of CO_2 (OSRAM)

Industry Transformation



Haitz's Law



Haitz's Law: Every decade, the cost per lumen falls by a factor of 10, the amount of light generated per LED package increases by a factor of 20, for a given wavelength (color) of light

Source: DOE 2008 Multiyear Program Plan, referencing Roland Haitz and Lum

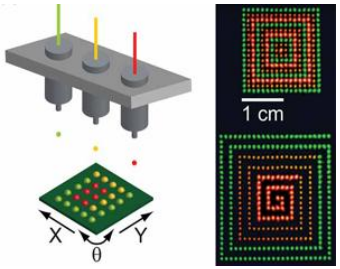
Revolution in Smart Lighting

- Fully integrated systems with sensors and controls
- Any color, any time
- Data with illumination
- Illumination with video
- Pollution and health monitoring
- Biochemical sensing and mitigation
- Circadian corrected lighting
- Adaptive lighting

MEMS

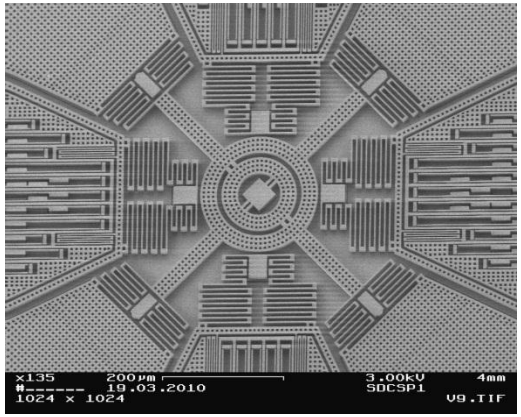
Nintendo Wii

Apple iPhone

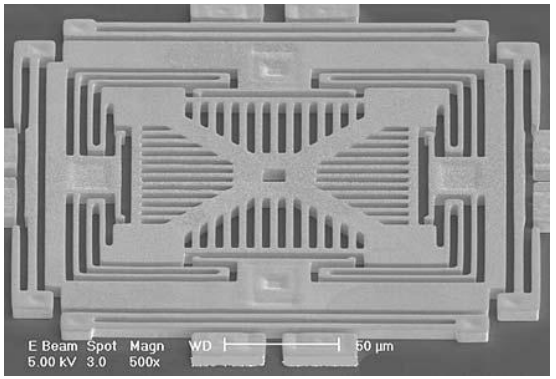


What are MEMS

- Micro-Electro-Mechanical Systems, or MEMS technology are miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the semiconductor fabrication techniques.

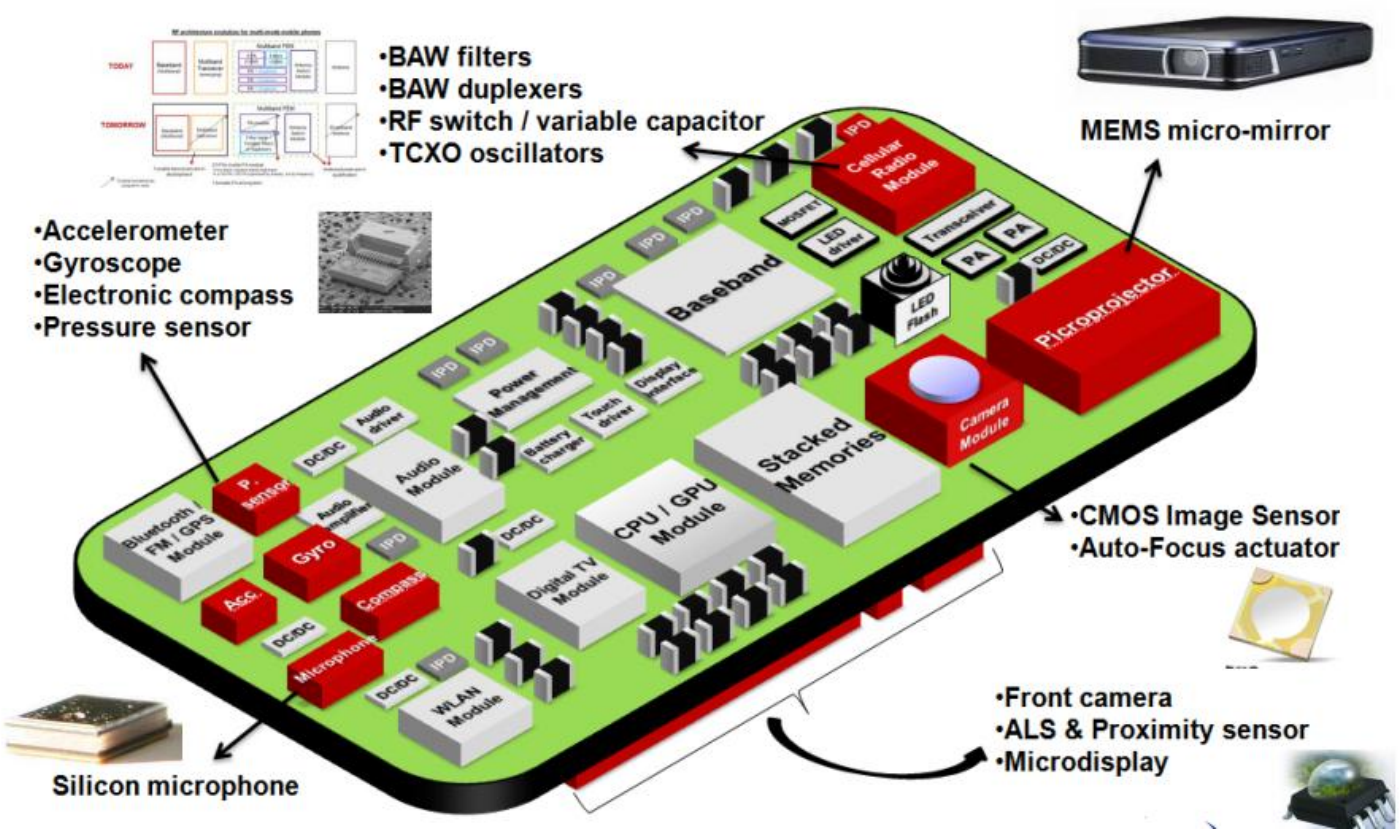


MEMS Gyroscope (iMicronews)



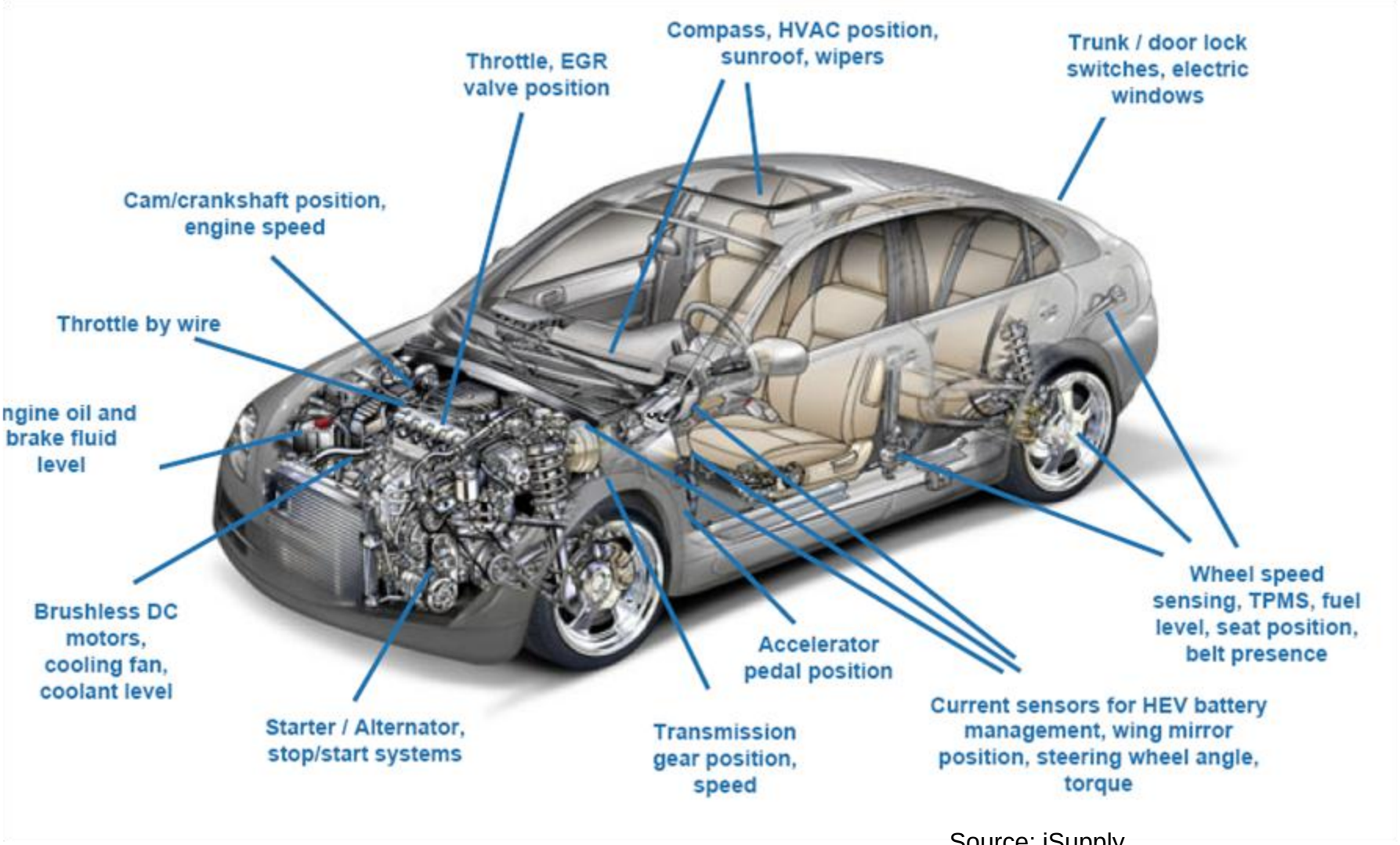
MEMS Accelerometer (Sensors Magazine)

MEMS in Mobile Phones



Source: Yole Developpment

MEMS in Automotive

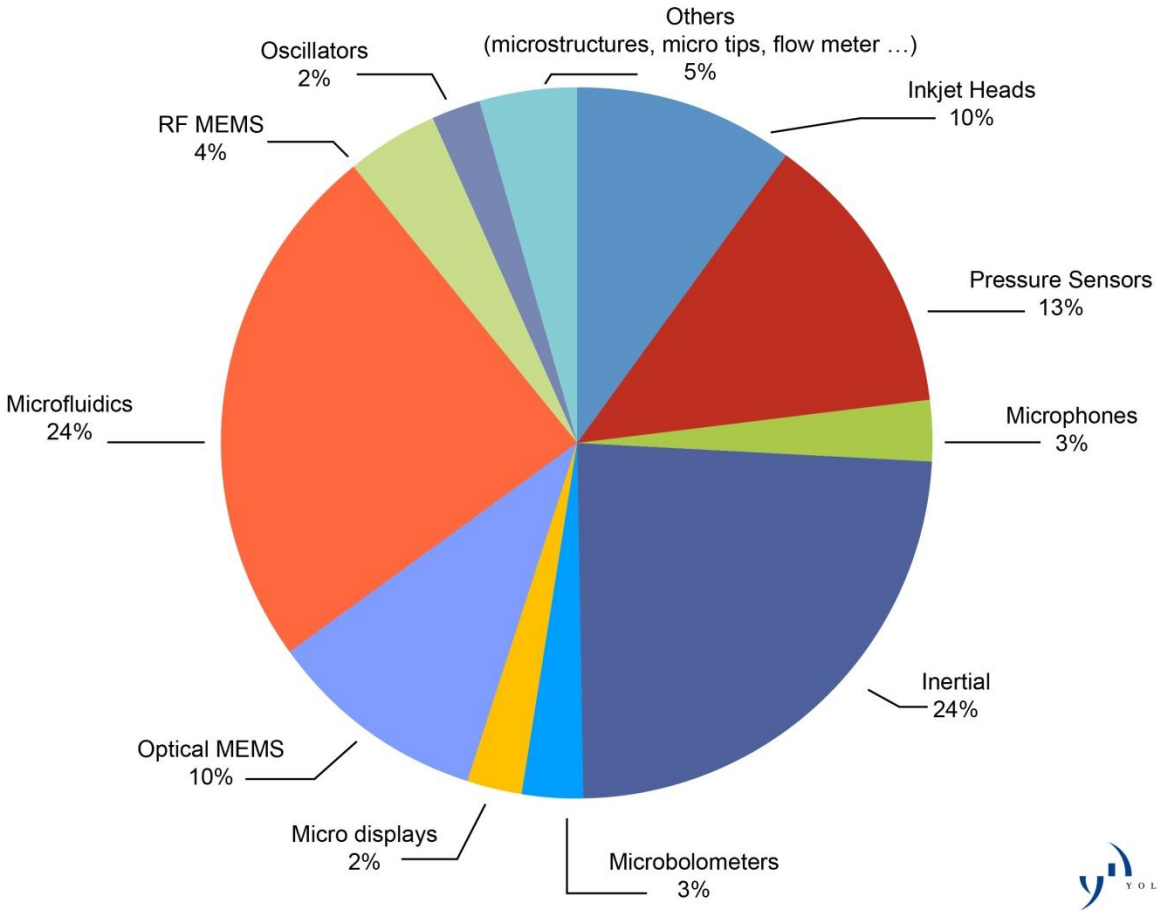


Source: iSupply

MEMS Market

2016 MEMS market value breakdown - Total : US$ 19,6B

(Status of the MEMS industry report, September 2011, Yole Développement)

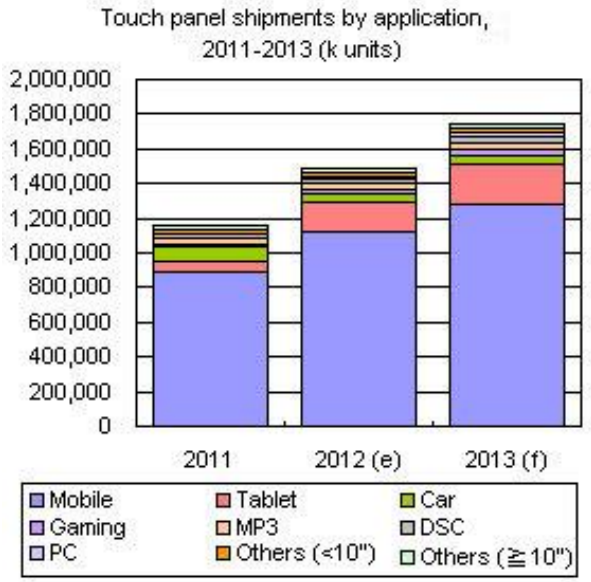


Sensors Everywhere

"Our HP Labs team has a vision for this called CENSE—Central Nervous System for the Earth—a really far-reaching vision about all the different ways c gathering information from the environment, from traffic from [a person's] physical health, from structural health [of buildings and bridges], and taking that data and using it to make decisions."

The End of Keyboards?

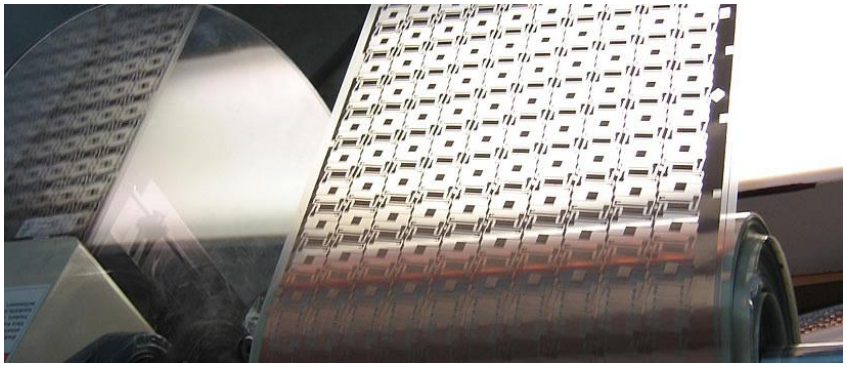
- Global touch screen shipments are expected to reach 1.75 billion in 2013, up 17.2% on year.
- Multi-point, capacitive touchscreen panel consists of an insulator such as glass, coated with a transparent conductor such as indium tin oxide (ITO).

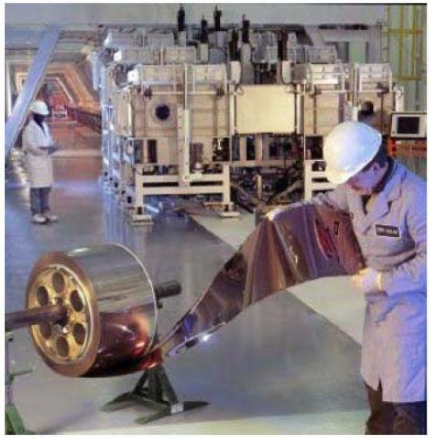


Source: iDigitimes Research

Printed and Flexible Electronics

- The use of printing methods to create electrical devices
- Organic and inorganic materials
- Sheet-based and roll-to-roll-based approaches
- Inkjet and screen printing used for low-volume, high-precision work
- Gravure, offset and flexographic printing more common for high-volume production



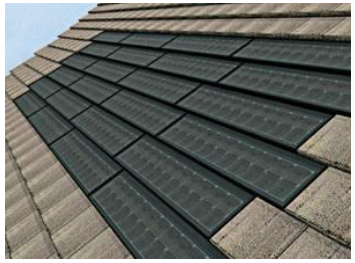


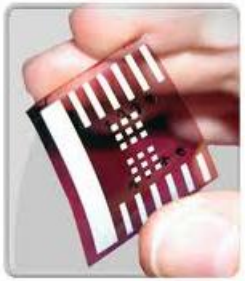
Printed Electronics in Action

Printed Batteries
Eufucell

New Solar Powered
Touch Screen Notebook
(AUO)

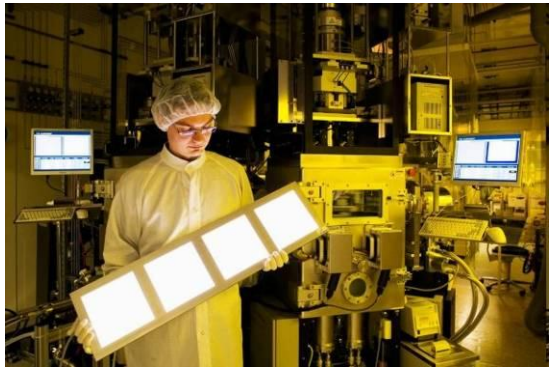
Solar Shingles from Dow;
DuPont in planning.





RFID Tag
Kovio

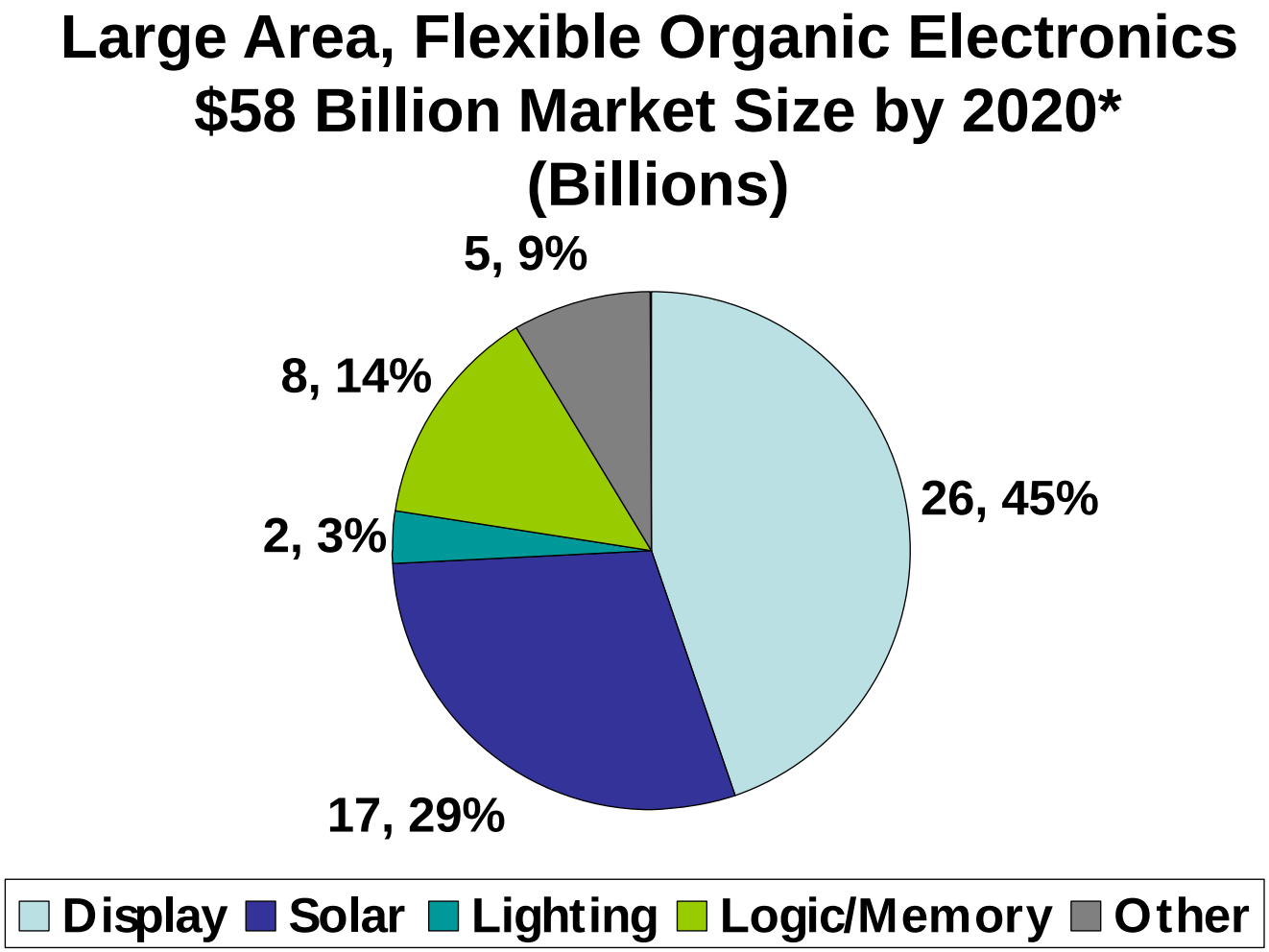
Amazon Kindle eBook



OLED Lighting (Fraunhofer IMPS)

OLED Display
Creative Labs

Large, Area Flexible Electronics



* Source: iNemi Roadmap, 2011, Nanomarkets, IDTechEx

Thin Film Solid State Batteries

Capacity Need	Market Size
<30mAh	~$50M *Large potential*
30mAh – 1Ah	>$600M *Expanding*
>1Ah – 20Ah	>$6B *Established*

Sources:
1) Avicene Energy, "The Rechargeable Battery Market and Main Trends 2011-2020 "
2) NanoMarket, "Printed Battery Markets--2011" and "Thin-Film Batteries: A New Market Opportunities Assessment—2011"

OLED Displays

- OLED (organic light emitting diodes) are solid-state devices composed of thin films of organic molecules that create light with the application of electricity.
- Common in mobile handset screens
- Samsung, LG have introduced 55” TVs
- Estimated $35 billion in sales by 2018 (DisplaySearch 2012)

LG OLED TV, CES Show 2012

Demonstration of a 4.1" prototype flexible display from Sony

A Day in the Life of Glass

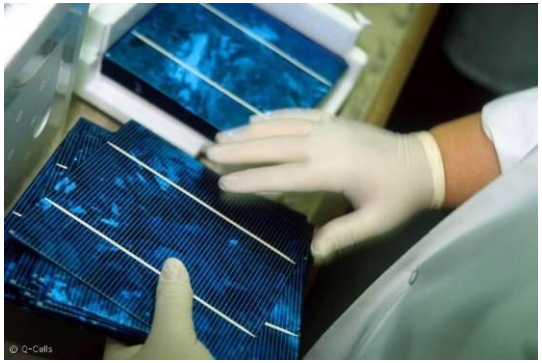
http://www.youtube.com/watch?v=MHqrrki47ec

Printed Electronics Technical Barriers

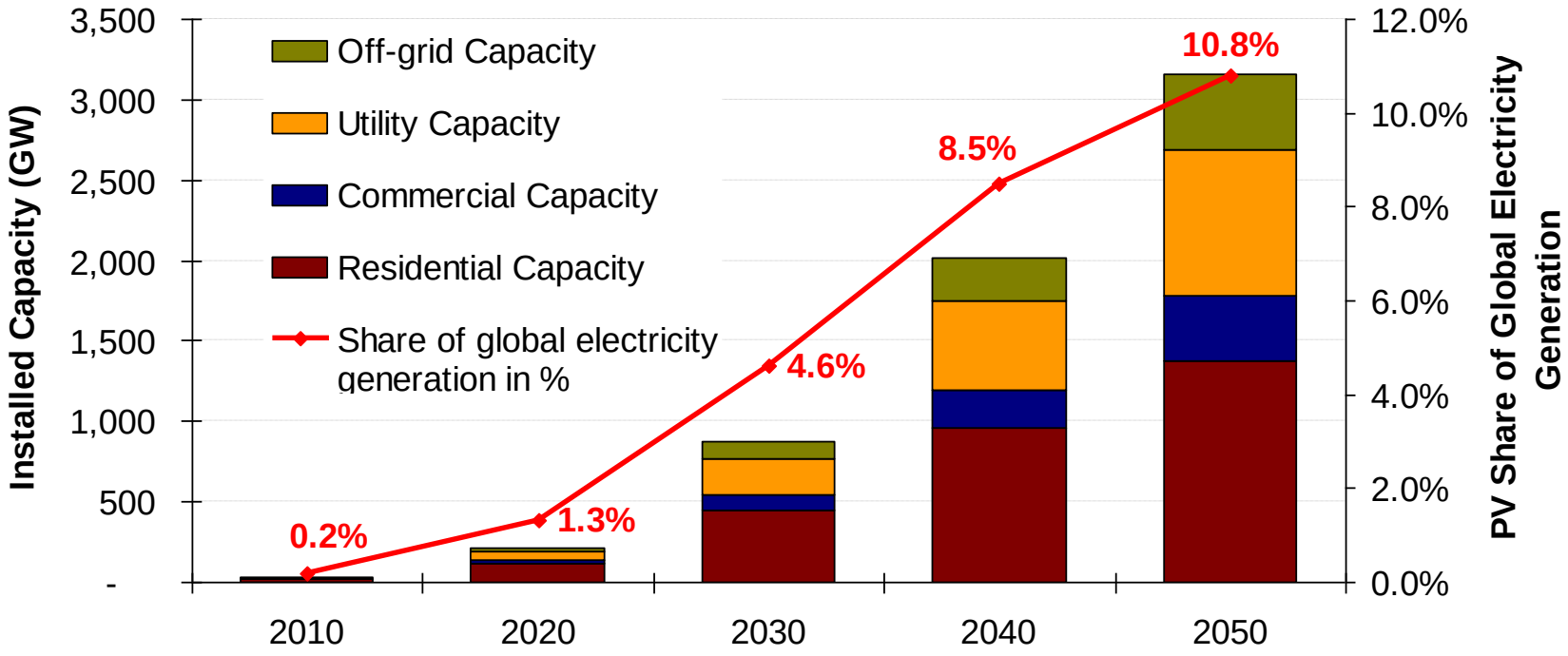
- Inks: conductive, dielectric, semiconductor, resistive, lighting emitting, photovoltaic
- Substrates: polymer films (PEN, PET), metal, paper, textile, ceramic, glass
- Packaging Barriers: films, barrier films, coatings
- Electrical design, layout, simulation, workflow
- Manufacturing Platforms: screen, gravure, inkjet, flexography, thermography, lithography, electrophotography, et.
- In line, Offline Metrology, Test, Characterization

Source: Heliatek

Solar Photovoltaics



PV and Solar Energy

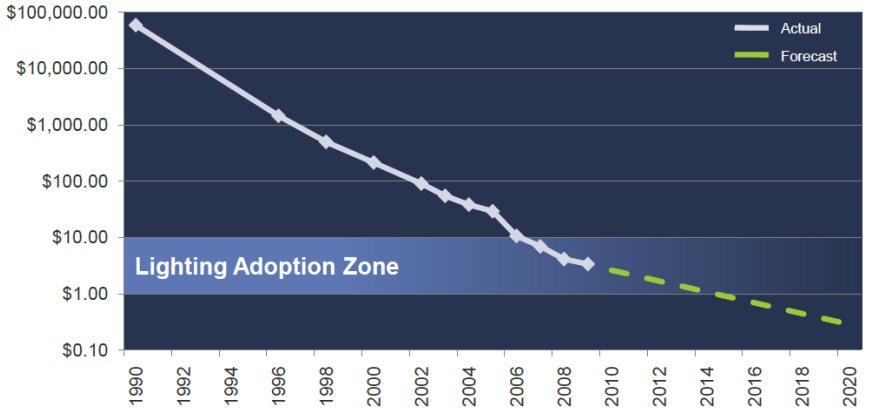


- ***According to the International Energy Agency, PV will provide around 1.3% global electricity production in 2020 and will go up to 11% by 2050.***

How Industry's Scale

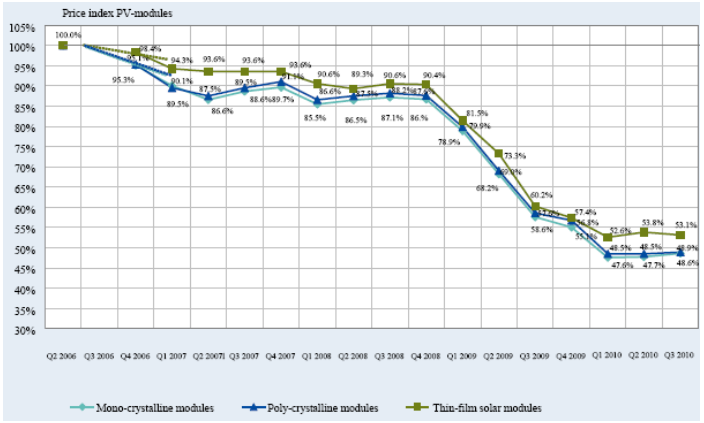
- Innovation
- Specialization
- Global Markets
- Standards
- Industry Collaboration

LED Cost Per Lumen



Cree, 2011 DOE SSL R&D Workshop

PV Module Prince Index



EuPD Research 2010

Driving the Electronics Revolution

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Webinar Recordings

To access this recording, slides and handout visit

nano4me.org/webinars.php

2013 Events Calendar

February 22: *Webinar*	Nanotechnology Demos & Simulations
March 22: *Webinar*	Trends in Nano: Program Development (Three Part Series)
April 15-18: *Workshop*	Course Resource Workshop I: Safety, Processing & Materials
April 26: *Webinar*	Successful Models for Nano Outreach

Visit www.nano4me.org/webinars for more details about these and other upcoming webinars.

Thank You!

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