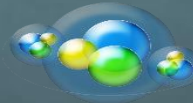




Electronics Materials Information



Worldwide Market Trends & Materials Issues

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Techcet Group

a Techcet CA LLC Company

CMC Conference 2016

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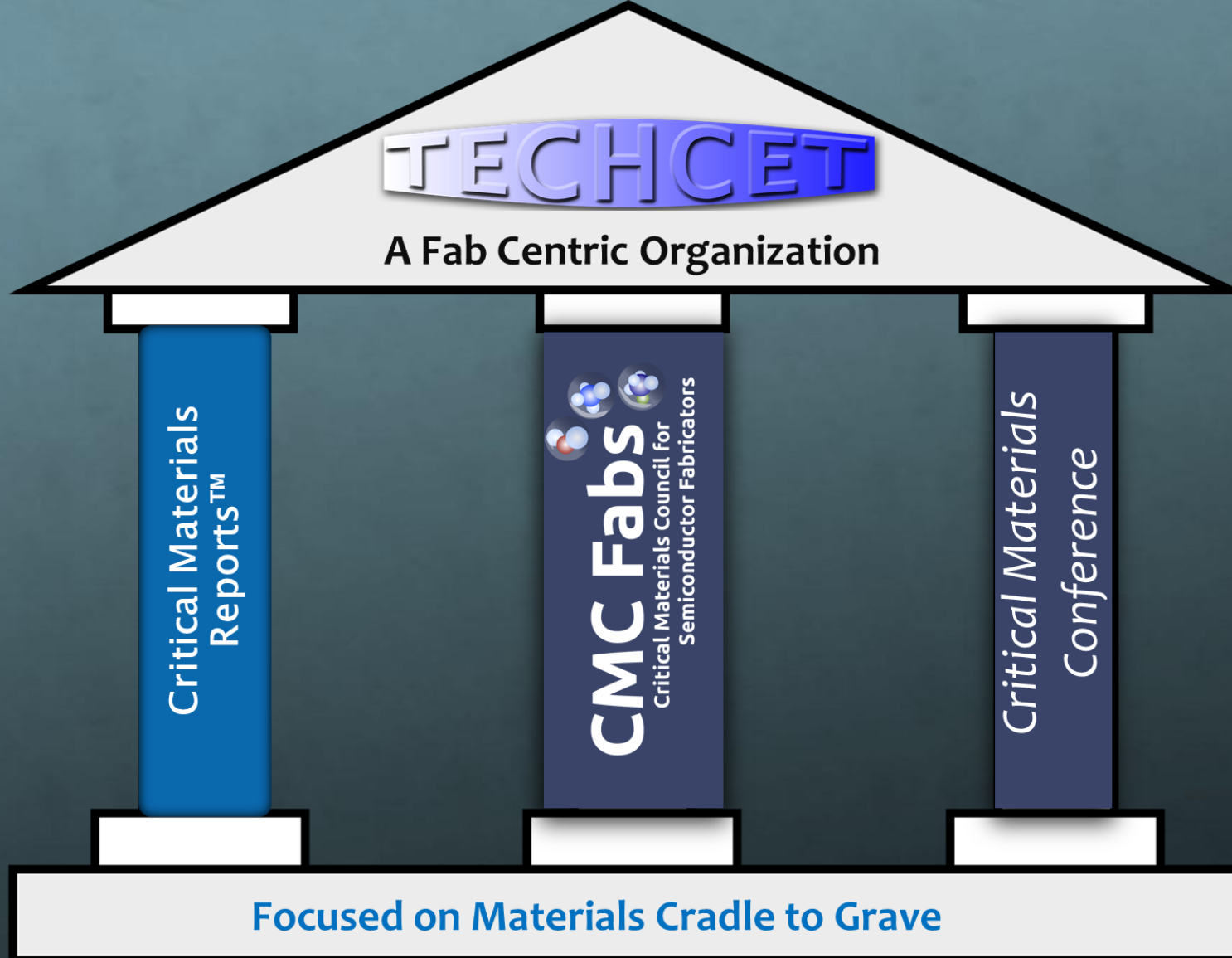
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Outline

-  Introduction
-  World Economic Influencers
-  Business and Technical Trends for Materials
-  Strategic Materials Trends
-  Summary

Disclaimer

- This presentation represents the interpretation and analysis of information generally available to the public or released by responsible agencies or individuals. Data was obtained from sources considered reliable. However, accuracy or completeness is not guaranteed. This report contains information generated by Techcet by way of primary and secondary market research methods.



*The CMC is a membership group of leaders in Semiconductor Device Fabrication, see: www.cmcfabs.org

- 🌐 Technology Centered, Semiconductor Materials Market & Supply Chain Analysis
- 🌐 Started in 2000 to Support Sematech CMC, ISMI & Materials Supply Chain
- 🌐 Member SEMI CGMC > 15 yrs

Techcet Group Analysts

- 10 technical market analysts for > 12 material market segments Analysts from the supply chain
- > 200 years Combined Semiconductor Industry Experience
- ~ 150 years Semiconductor Process Engineering Experience
- ~ 120 years Specific Market / Supply Chain Analysis Experience
- Technical Experience directly from the Supply Chain
- Each Analyst has been chosen based on
 - Vetting through >10 years working relationship
 - High integrity
 - Material Supply Chain and Market Analysis Experience

Critical Materials Reports™

Material Expertise

 Electronic Gases

 Wet Chemicals & Specialty Cleaning

 CMP Consumables

 Slurries / Abrasives

 Pads / Conditioners

 Photoresists

 Sputtering Targets

 Silicon Wafers

 Dielectric Precursors

 ALD / CVD Metal Precursors

 Equipment Consumables

 Quartz

 Graphite

 Silicon Carbide

 Ceramics

 CMP Parts

 Packaging Process Materials

WW News & Impact on the World's Economy

WW News



China Economy Softening causing issues in US stock market which may lead to decline in consumer confidence.



Japan Economy and Supply Chain Shift

- Earthquake / Nuclear Meltdown destabilizing economy
- Electronic industry shrinking
- Electronic Materials becoming an net export market



Worldwide Population Changing

- Impact to Spending

Impact

- Lower sales demand from China can create a negative impact on manufacturing across the world.
 - Lower production
 - Layoffs and fewer jobs
 - Reduction in consumer spending
- China still a growing market with opportunity to sell chips/electronics. However, growing competition from China materials suppliers creating pressure on others.
- Japan, latest Earthquake causing downward cycle in stock market. Consumer confidence rattled.
- WW Semi Market dependent on Japanese materials; those companies are in jeopardy because they must export and keep prices to maintain viability.
 - economy is uncertain, esp after the Kumamoto earthquake and nuclear melt down.

The World is Changing



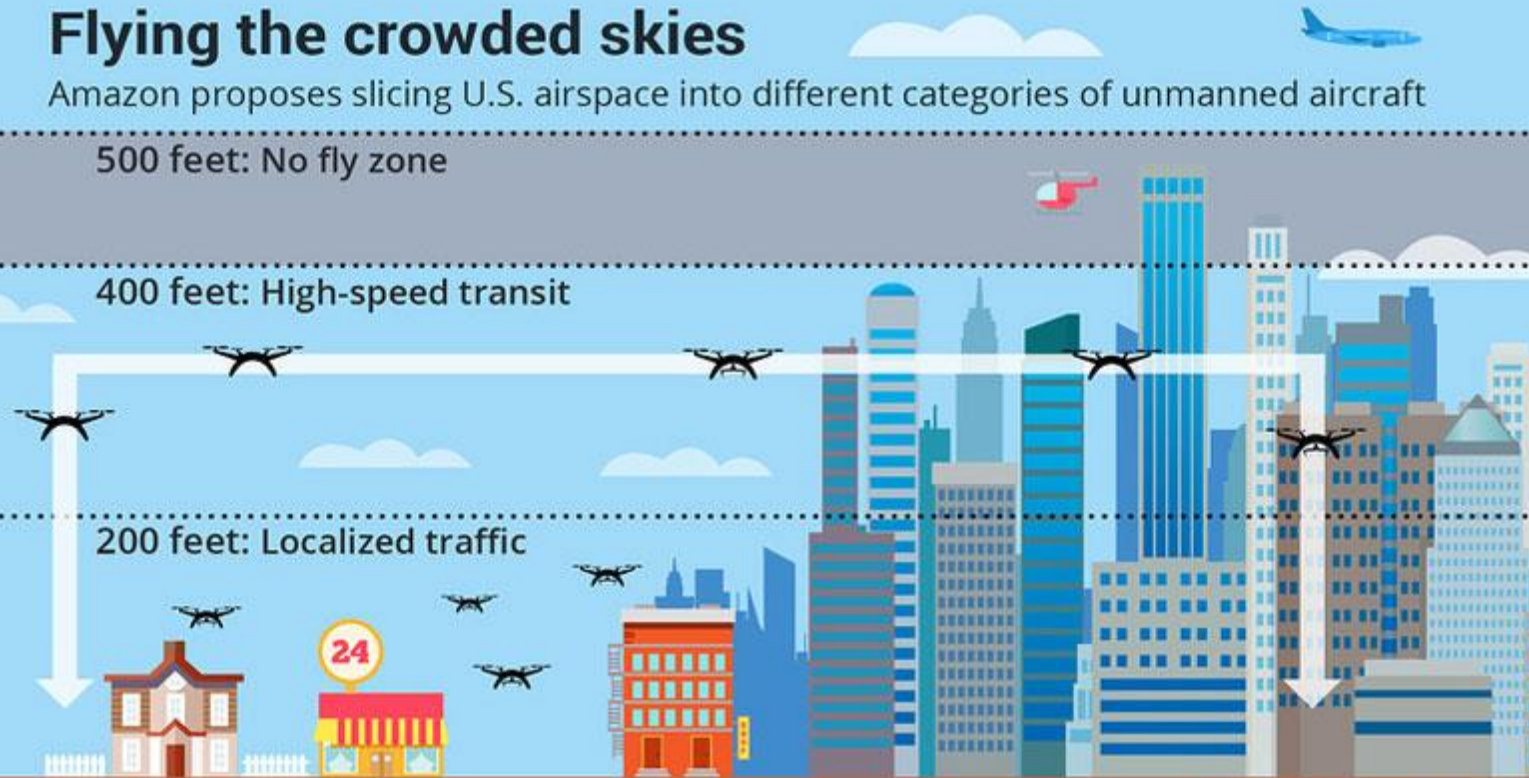
Flying the crowded skies

Amazon proposes slicing U.S. airspace into different categories of unmanned aircraft

500 feet: No fly zone

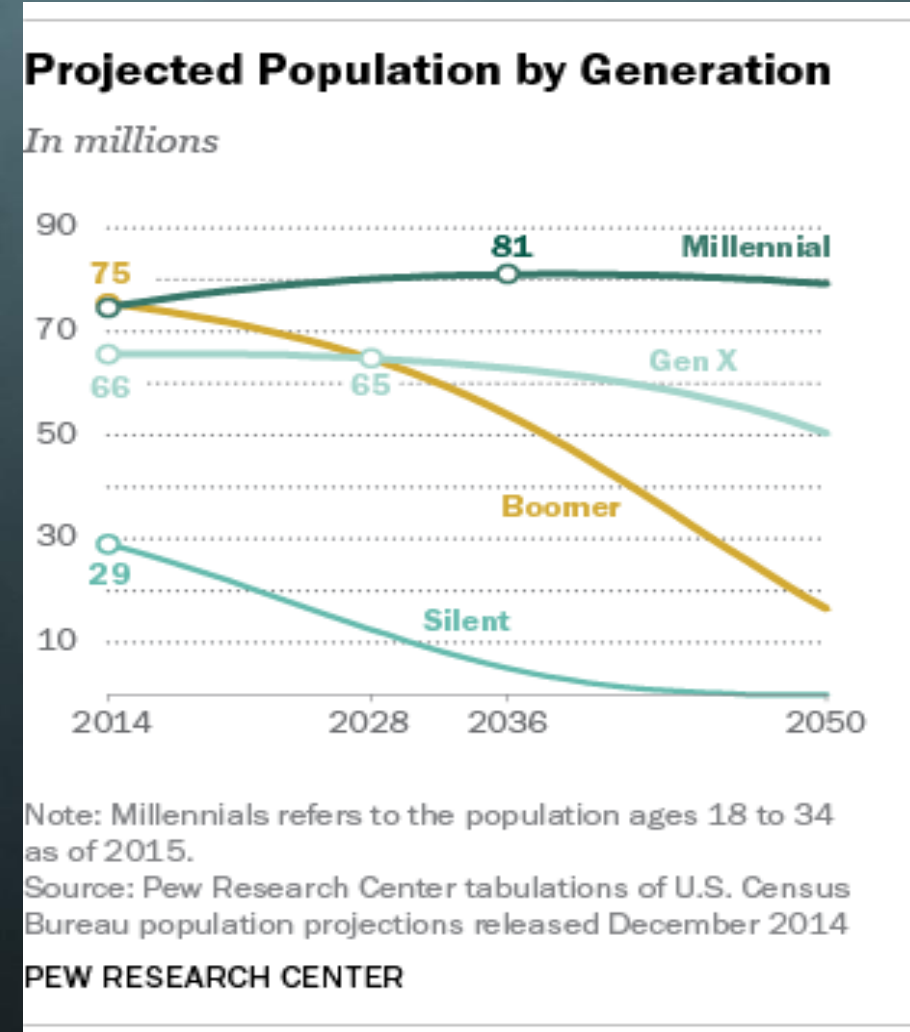
400 feet: High-speed transit

200 feet: Localized traffic



The Next Generation of Users of Electronic Stuff

- 🌐 This year, the “Millennial” generation is projected to surpass the Baby Boom generation as the nation’s largest living generation, according to the population projections released by the U.S. Census Bureau last month.
- 🌐 Millennials (ages 18 to 34 in 2015) ~75.3 million, surpassing the what was the largest population segment in the US, the Boomer ~74.9 million (now ages 52 to 70).
- 🌐 In China, “the two largest populations are the 20-24 age group and the 60-64 age group”[8]

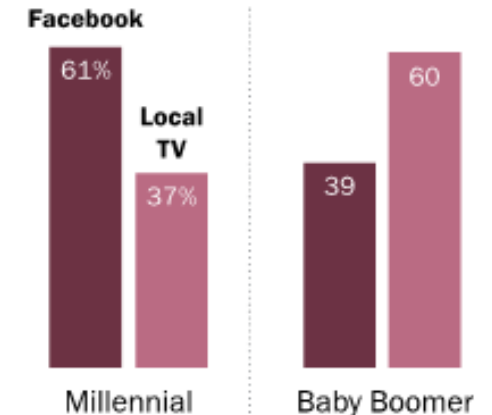


The Next Generation of Users

Millennials (people ages :18-34 by 2015) [1-5]	
Will buy	Instead of buying
<ul style="list-style-type: none"> • Cell phones • Tablets • Laptops 	<ul style="list-style-type: none"> • TVs • Less desktop computers
<ul style="list-style-type: none"> • Bicycles; mass transit user 	<ul style="list-style-type: none"> • Cars
<ul style="list-style-type: none"> • Rent before buy, instead “Tiny Home” 	<ul style="list-style-type: none"> • Buying a house right away
<ul style="list-style-type: none"> • Online delivered to door 	<ul style="list-style-type: none"> • Bulk purchases
<ul style="list-style-type: none"> • Electronic stuff to track their aging parents 	<ul style="list-style-type: none"> • Service support

Millennials and Baby Boomers: A Generational Divide in Sources Relied on for Political News

% who got news about politics and government in the previous week from...



American Trends Panel (wave 1). Survey conducted March 19-April 29, 2014. Q22, Q24A. Based on online adults.

PEW RESEARCH CENTER

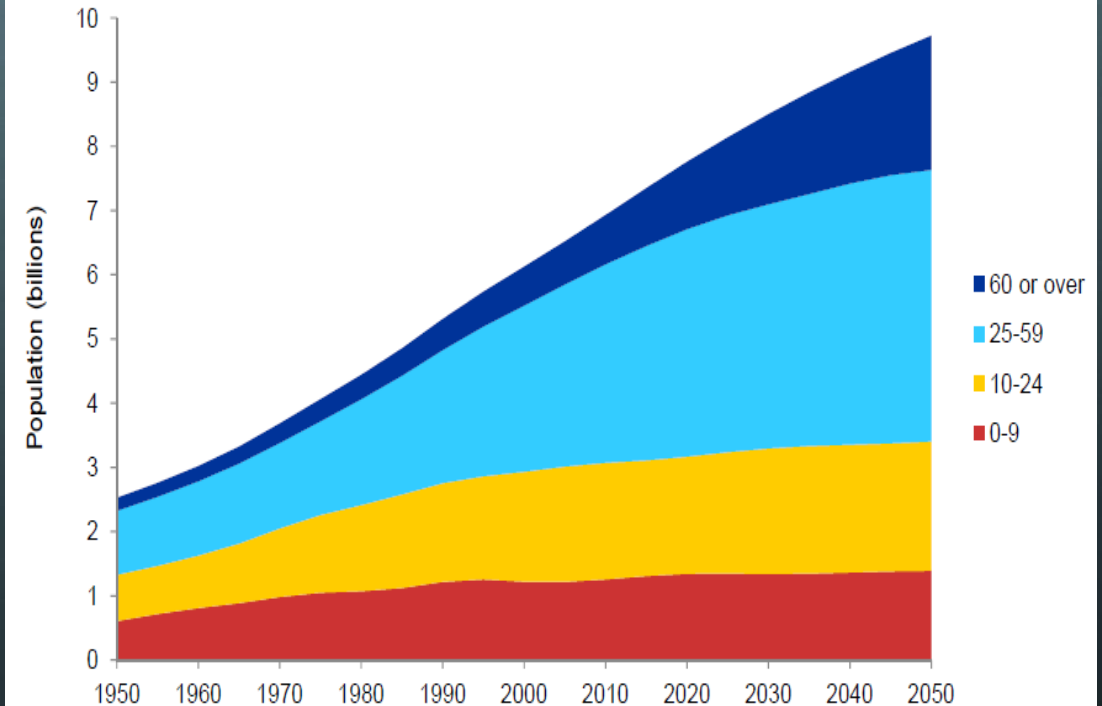
🌐 54% of people ages 14-24 consume their media on phone, tablet, or PC – “many young people aren’t getting a TV at all”[1]

A Look at the Boomer Population

Baby Boomers (people ages :52-70 by 2015) [9]

Will buy /Need (electronics)	Instead of buying
• Convenience Electronics, i.e. sensors/control systems to allow for decreased agility	• Cool Gadgets
• Medical Devices and Monitoring	• ?
• Medical Implants	• ?
• Adjustable / Hi-Tech Beds/mattresses	• Tech outfitted electric cars
• Online delivered to door	• Going out

Global population by broad age group, 1950-2050



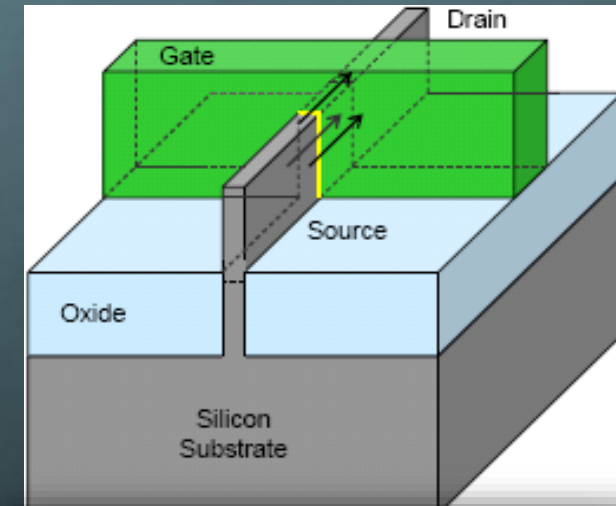
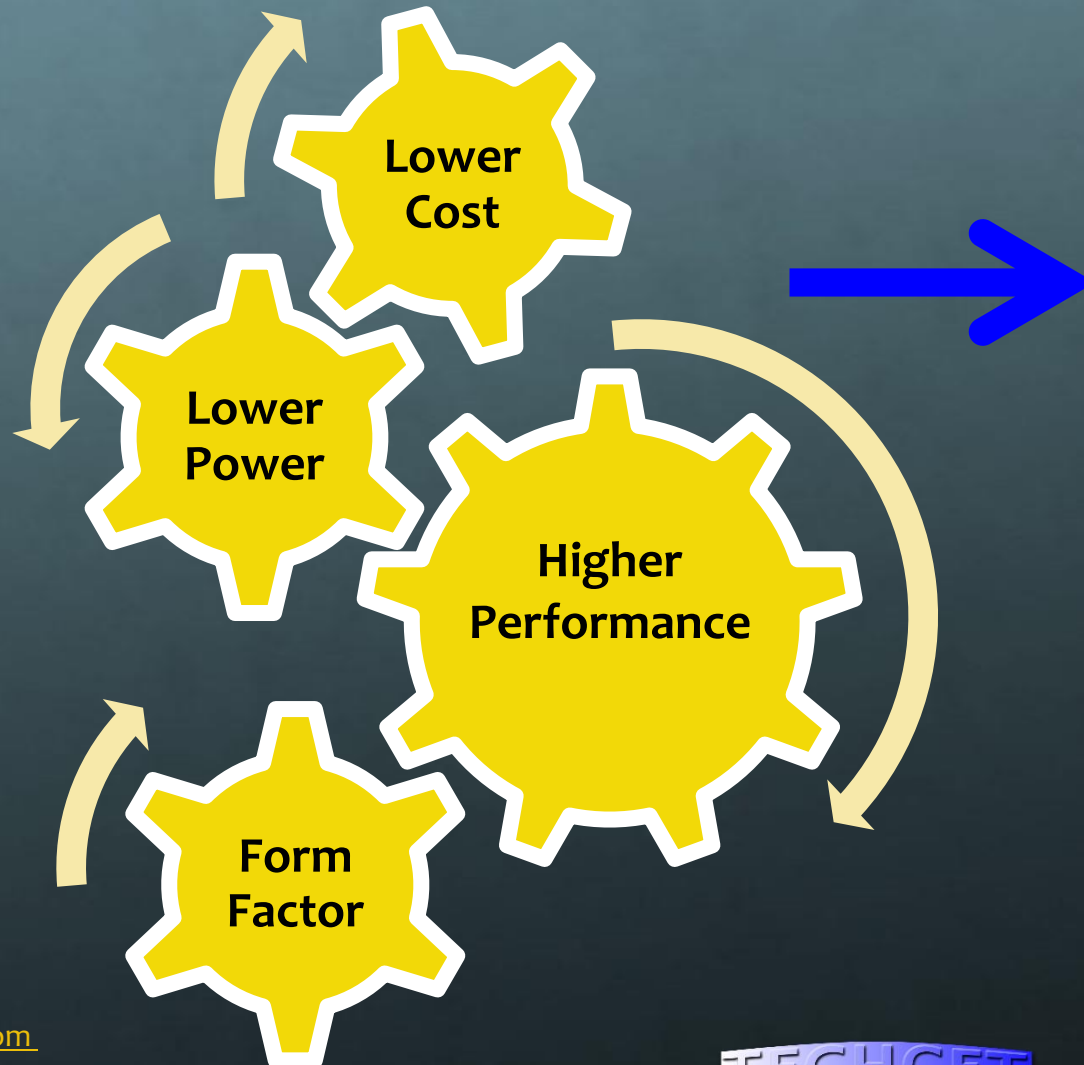
Data source: United Nations (2015). *World Population Prospects: The 2015 Revision*.

Source: UN 2015 [10]

How these Populations Impact Electronics Markets?

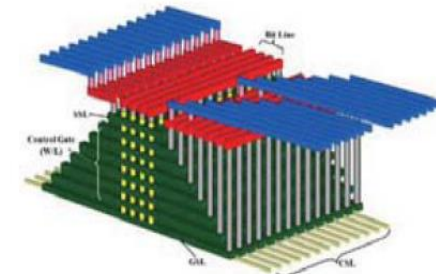
- 🌐 Growing Portable Device Market will Continue to push need for low power, compact devices, <65nm & leading edge
- 🌐 Growing dependencies on China will cause continued stress in the supply chain
- 🌐 Internet Connectivity Demands Grow
 - 🌐 # wireless devices & operating frequencies → RF growth
- 🌐 Continued need and dependency on more smart, portable, electronics stuff and smart systems which manage big data to accumulate, analyze and assess, a multitude of things, i.e. diagnosis disease, buying habits, improvements in inventory control, material movement, etc.

Device Requirements Driving Materials



SemiWiki

TCAT



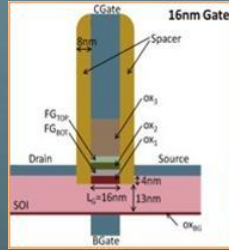
[J. Jana et al., 2009 VLSI Tech.]

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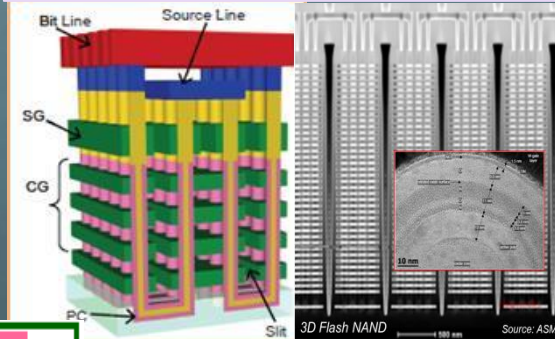
IC Technology Roadmap Evolutions/Revolutions

Note "Node" is "nm" performance, physical is GLph

**Non-Volatile 1X & 1Z nm
Shrink Planar NAND**



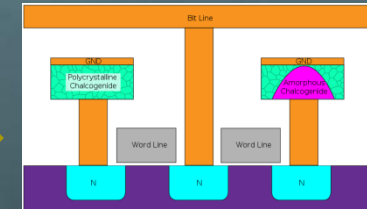
**Non-Volatile 80-30nm features
3D NAND (BiCS, TCAT, etc.)**



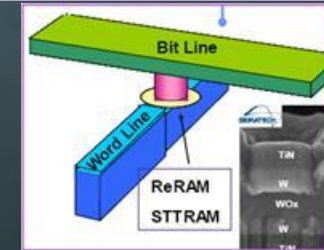
Charge Trap Flash in Vertical Plane
also called 3D or V-NAND

3D/V-NAND Extend 5+ yrs
16 to 256 layers

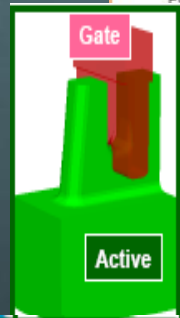
**Non-Volatile <10nm
CNT? PCM**



**RAM & Non Volatile ?
18-15nm STT-MRAM**



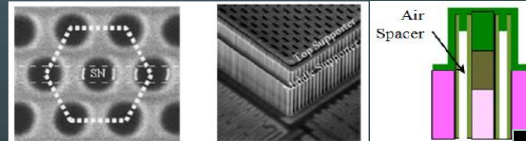
**DRAM 32-28nm
Vertical Capacitors**



Saddle Fin FET

**DRAM
26-16nm
HkMG +
Si Fin**

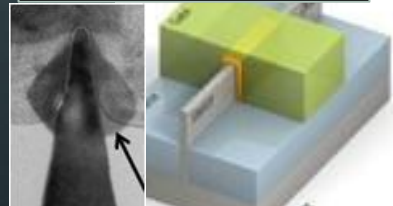
Continue DRAM Shrink w/ MPU
Honey comb cell + Air-gap spacer



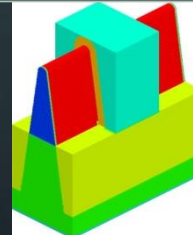
**20nm Planar
SOI Hk/MG**



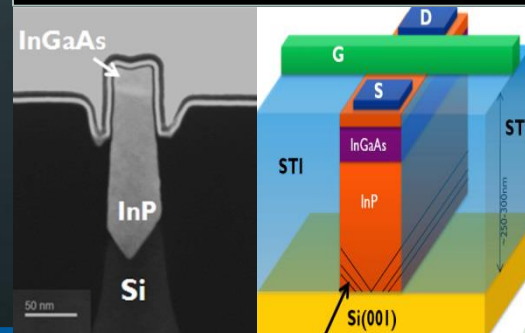
**14nm TriGate
14/16nm FinFET-STI**



**10nm
Fin w/ STI,
channel change?**



**7nm
III-V or Ge ?**



**EUV
7nm ?**

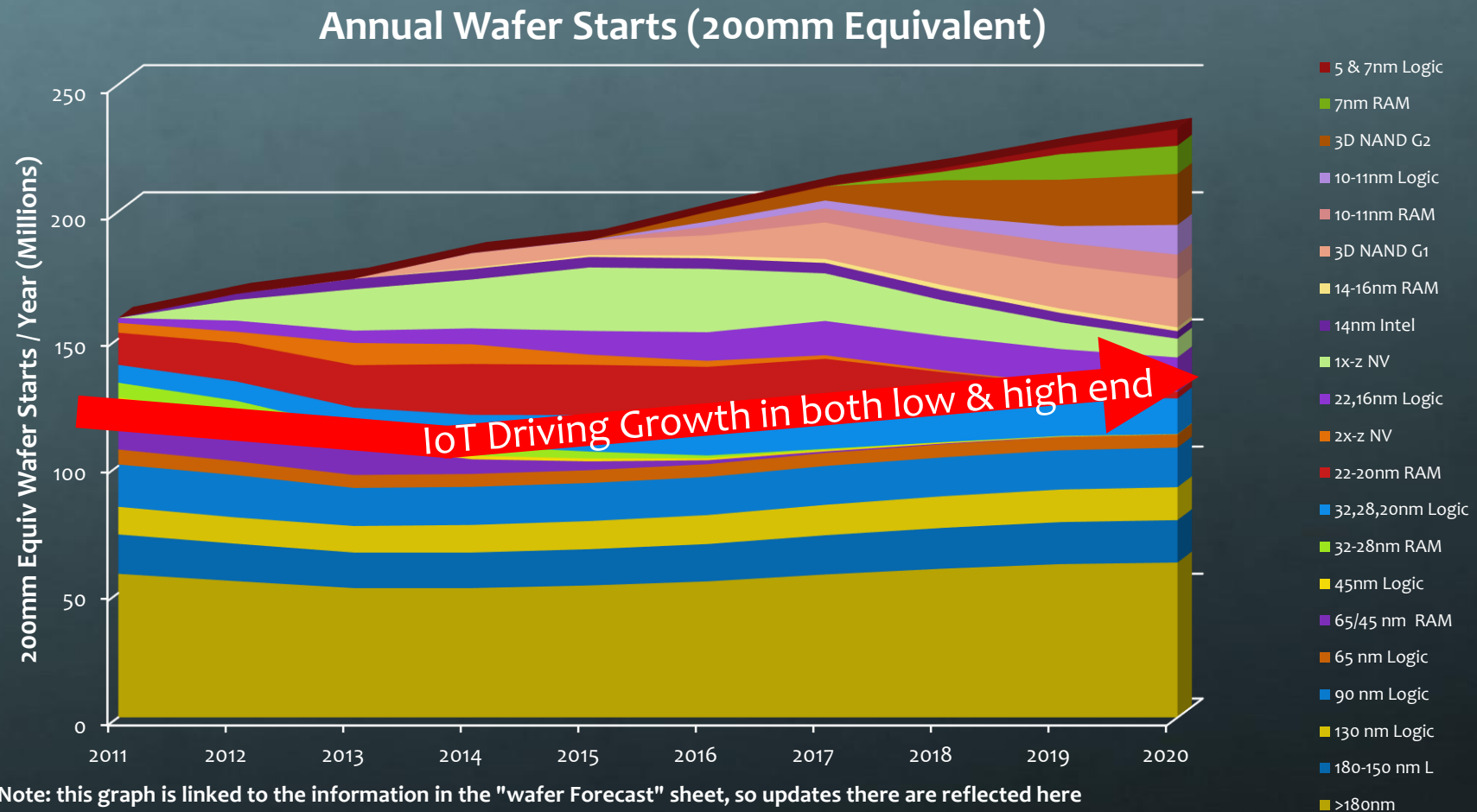
**450mm
7nm?**

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2013 2014 2015 2016 2017 2018 2019

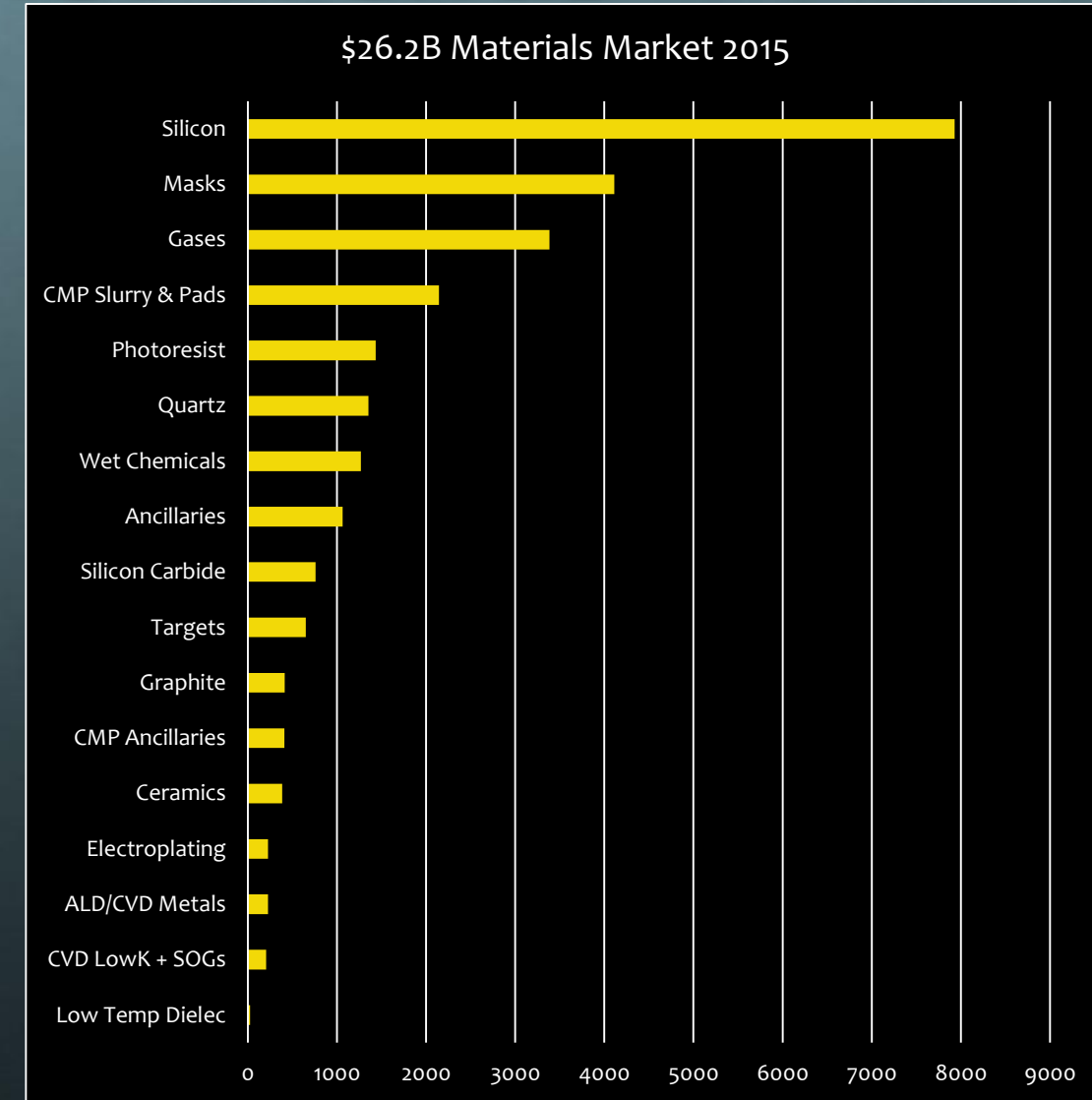
Millennials & Baby Boomers Push Growth in IoT

Wafer Starts per Year (200mm equivalent)



Materials Market Trends

- Total Market ~\$26.2B in 2015 CAGR 4%, 2015-2020.
- Improved drive for more process control, cost reduction
 - Multi patterning
 - Planar to 3D (3D NAND, FinFET)
- Increase in number and volume of materials for each technology node.
- Little need for novel materials until <10nm;
 - cobalt although not novel was new to semi processing -barrier.
- Small Form Factor, Multi-Die and SiP applications are driving Advanced Packaging , i.e. 2.5/3D stacking, InFO, TSV, WLP, PoP
- Increasing Concerns regarding Waste Management / Handling of Materials



Source: SEMI, SST, semimd

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China Supply Chains

Sputter Target Market 2015 in China

🌐 Semiconductor Dependency

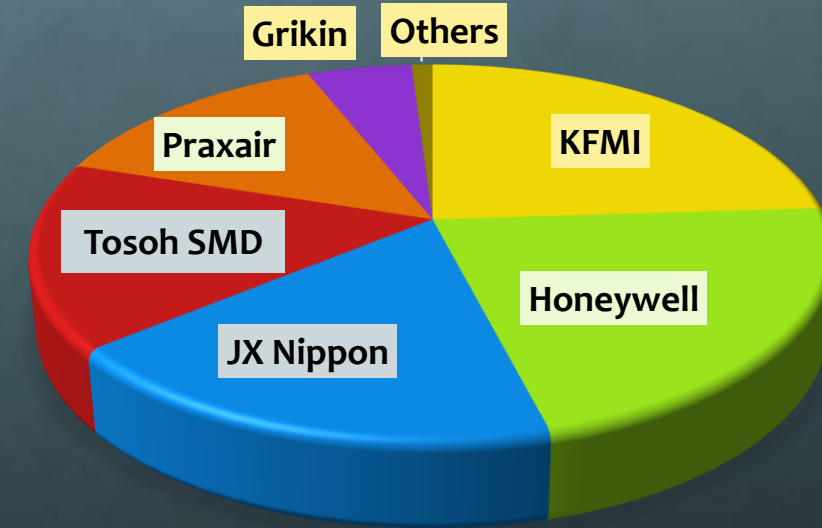
- 🌐 Raw Metals: W, Mo 🌐 Refined Metals: Ti, Co
- 🌐 Minerals: F, P 🌐 Rare Earths: Ce

🌐 Aggressive Predatory Pricing Strategy – Chinese Suppliers have appreciable share within China today!, i.e. sputtering target market

🌐 Attracting many fabs to establish manufacturing sites in China with tax incentives, attractive real estate deals and regulation policies.

- | | | |
|-----------|--------|--------------------|
| 🌐 Intel | 🌐 SMIC | 🌐 XMC |
| 🌐 Samsung | 🌐 UMC | 🌐 Hua Li MicroFabX |
| 🌐 Hynix | 🌐 TSMC | |

🌐 Supply Chain is growing, and MUST grow to support these fabs.



Material Trends Impacted by Population Dynamics

- 🌐 Silicon Growth for high and low tech nodes strong >3%
- 🌐 All legacy materials will follow in the same step
- 🌐 Leading edge materials will continue to grow, i.e. Precursors for BEOL and for Multi-patterning > 12% CAGR
- 🌐 EUV coming but expensive - materials and energy consumption
- 🌐 CMP Materials will continue to grow >5% CAGR; esp driven by 3DNAND

Summary & Take Aways

- Materials Supply Segments will continue growing
 - CMP ... increases for 3D NAND and FinFET CMP passes
 - Litho ... multilevel patterning for <22nm
 - ALD / CVD Precursors
 - Neon
 - Raw Materials Increasingly Important
- China has great influence on the world's Economic Stability and Consumer Spending
- The changing populations are impacting what people buy and buying habits; influencing consumer spending, in turn, semiconductor market growth
- M&A activity alive again and well – Watch out for Moves from Asia (Korea and China)
- TEHCET is your materials market and supply chain expert.

Techcet Group Analysts (& Experience listing)



Lita Shon-Roy – President / CEO

- Rasirc/Matheson Gas, IPEC/Athens, Air Products



Karey Holland, Ph.D. – Chief Technical Officer

- MegaFluid Systems, FEI, NexPlanar, IPEC, Motorola, IBM



Sue Davis – Director, Business Development

- TI, Sematech, Motorola, Rodel/DOW



Yu Bibby, Ph. D. – Sr. Technology Analyst

- UV Global, ipCapital Group, Wilkes University



Jerry Yang, Ph.D.– Sr. Technology Analyst

- Sematech, Rohm & Haas, Rodel, IPEC, LAM



Mike Fury, Ph.D. – Sr. Technology Analyst

- IBM, Rodel, EKC, Vantage



Mike Walden, Ph.D. – Sr. Technology Analyst

- SunEdison/MEMC, SUMCO, IBM



John Housley – Sr. Advisor

- EKC Technologies, KTI, Union Carbide, Motorola



Jonas, Sundqvist, Ph.D. – Sr. Technology Analyst

- Fraunhofer, Quimonda



Ed Korczynski – Sr. Technology Analyst

- Solid State Technology, Intermolecular, Nanomarkets, Applied Materials, WJ



Tim Dyer – Sr. Technology Analyst

- Elcon, Matsci, Morgan Ceramics IPEC/Speedfam



Bruce Adams – Sr. Technology Analyst

- Matheson Gas, Air Products, & Chemicals, Honeywell



Brooks Hurd – Sr. Technology Analyst

- Air Products & Chemicals



Chris Michaluk – Sr. Market Analyst

- H.C. Stark, Climax Molybdenum, Williams, Cabot SuperMetals



Chris Blatt – Sr. Market Analyst

- Air Products, IPEC/Athens, Zeon Chemicals



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References:




- [1] <http://techcrunch.com/2013/03/11/zero-tv-households-now-at-5-million-says-nielsen-up-from-3-million-in-2007-but-still-just-5-of-market/>
- [2] <http://blogs.denverpost.com/beer/2014/05/02/pete-coors-grappling-ever-changing-world-beer/13551/>
- [3] <http://finance.yahoo.com/blogs/the-exchange/real-reason-millennials-don-t-buy-cars-homes-153340750.html>
- [4] <http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/son2012.pdf>
- [5] <http://www.theatlantic.com/magazine/archive/2012/09/the-cheapest-generation/309060/>
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- [7] <http://www.economist.com/news/briefing/21601248-generation-old-people-about-change-global-economy-they-will-not-all-do-so>
- [8] http://www.hsph.harvard.edu/program-on-the-global-demography-of-aging/WorkingPapers/2010/PGDA_WP_53.pdf
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China's new Rare Earth Policy


- 🌐 As the results of WTO ruling, China eliminated its decades' long export tariffs and quota on rare earths elements including tungsten, molybdenum, iron and steel particles and other products. This leads to 5 major impact areas in China's rare earth Policy, as well as huge impact on the world rare earth industry and market:
- 🌐 1) China's new law for their rare earth industry:
 - 🌐 New law requires that China's rare earth industry integrates/restructures into six large State-Owned-Enterprise (SOE) groups: China Aluminum Group, China Minmetals Group, Northern Rare Earth Group, Xiamen Tungsten Group, Southern(Ganzhou) Rare Earth Group and Guangdong Rare Earth Industry Group.
 - 🌐 China believes this will “let Chinese rare earth industry to form a joint force to facing the outside world to change the current rare earth oversupply situation, effectively control the rare earth production and marketing.”
 - 🌐 China Treasury also established special funds to subsidize its Rare Earth restructure & exploitation. For example, on Aug. 2015, it issued subsidies of 458 million yuan to the Ganzhou Rare Earth Group for the development and comprehensive utilization of resources dedicated to rare earth, rare earth mine geological environment restoration.

China's new Rare Earth Policy Cont'd

2) China's new consolidated rare earth industry infrastructures:

-  China's Rare Earth industry enters the six State-Owned-Enterprise (SOE) groups era. No one else except this 6 SOE may engage rare earth activities.
-  In 2015, the newly formed Northern Rare Earth Group completed the integration of Baotou Steel Rare Earth in Inner Mongolia area with 6 other companies within the Inner Mongolia Region. The new law requires the Group to integrate all the rare earth mining, smelting and separation, utilization enterprises in the Inner Mongolia area and in Gansu province. As of now, total of 28 such enterprises has been consolidated into one roof under the Northern Rare Earth Group.
-  Consolidation in other part of the China is also near completion. China announced recently that it has completed the integration of the country's 77 rare earth mining permits (out of 78 total), and 77 smelting and separation enterprises (out of 99 total) into the 6 large State-Owned-Enterprise groups. It is expected to complete all the consolidation tasks early this year.

3) China's new tax law for their rare earth export:

-  When China eliminated its export tariffs on May 2015, they also implemented a new rare earth Resource tax law. The new Resource tax calculated by flat rates and rates varies by the regions and by the type of rare earths elements.

China's new Rare Earth Policy Cont'd

- Previously China's rare earth export tariffs are 15% for light rare earth and 25% for heavy rare earth respectively. Under the new Resource tax, the tax is calculated using the following formula:

$$\text{Resource Tax} = \text{Sale Amount} \times \text{Unit Price} \times \text{Resource Tax Rate\%}$$


- Resource tax rate% various by category and by region it came from:
For all heavy rare earth: Resource tax rate% = 27% for all regions.
For all light rare earth: Resource tax rate% = 11.5 % for the Inner Mongolia region,
= 9.5 % for Sichuan region,
= 7.5 % for Shandong region.

Examples of Resource tax rates for selected critical materials :




phosphor rock ==> 27%,
F (fluorspar) ==> 7.5 % to 11.5 % depend which region it came from
Ce (Cerium) ==> 7.5 % to 11.5 % depend which region it came from
W (Tungsten ore) ==> 6.5%
Molybdenum ==> 11%.

China's new Rare Earth Policy Cont'd

4) China's new law impact on the rare earth price trends :

-  With the sharp rise in China's Rare earth exports quantities, the price is in sharp decline. Statistics released by the China General Administration of Customs shown that China's exports of rare earth from Shanghai Customs Site was 8986 tons from Jan.-Dec. 2015, increase 42.2% compared to the same period of previous year, and the average export price of 119,000 yuan per ton , down 15.3% compared to the same period of previous year.

5) China's new law impact on the world-wide rare earth industry outside China:

-  With the sharp rise in China's Rare earth exports quantities and sharp decline in the price, many rare earth companies outside China struggles. On June, 2015, Molycorp, which mines rare-earth 15 elements at Mountain Pass, Calif., the only miner and producer of rare-earth elements in USA has filed for Chapter 11 bankruptcy after failing to turn a profit since 2011.
-  Today, 90% of the world's rare earths are produced in China. It would be closer to 100% but for Molycorp's output of cerium, lanthanum, neodymium, and praseodymium oxides and carbonates .
-  Mining companies outside China are now caught in a bind: They are working to increase output at a time when lower prices make it extremely difficult to turn a profit. Looking ahead, Molycorp will need to both increase production and obtain higher prices to survive, goals that can be mutually exclusive in today's market.