Electronics Materials Information

Presentation to Sematech Critical Materials Council

Lita Shon-Roy, President / CEO
Christopher Michaluk, Dir. Business Development

April 30, 2015

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Agenda

- Introduction
- Techcet's Materials Supply Chain and Supplier Market Info for Sematech
- Semiconductor Market Overview
- Electronic Gases Report Highlights
- Sputtering Target Report Highlights
- Report and Quarterly Meeting Schedule
- Wrap-up / Open Forum

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Introduction

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Introduction to Techcet Services Provided

Market Research

- Market Analysis and Forecasting
  - Market Size, Market Share
  - SWOT, etc.
- Supply Chain Analysis
  - Material Price Forecast
  - Supply Stability
- Technology Trends/Disruptions
- Business Trends
- Regulatory Matters

Business Intelligence

- Mergers and Acquisitions
  - Identify M&A Candidates
  - Due Diligence
- Business Strategy
  - Strategic Marketing
  - Business Planning
- Expert Witness
- Alternate Applications

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Introduction to Techcet

- Analysis of Supplier's Business Environment is a Key Component to
  - Business Continuity Management and
  - Category Management
- This is Techcet' s Focus
  - Process Materials Market Analysis and
  - Supply Chain Analysis
  - Risk Assessment & Analysis

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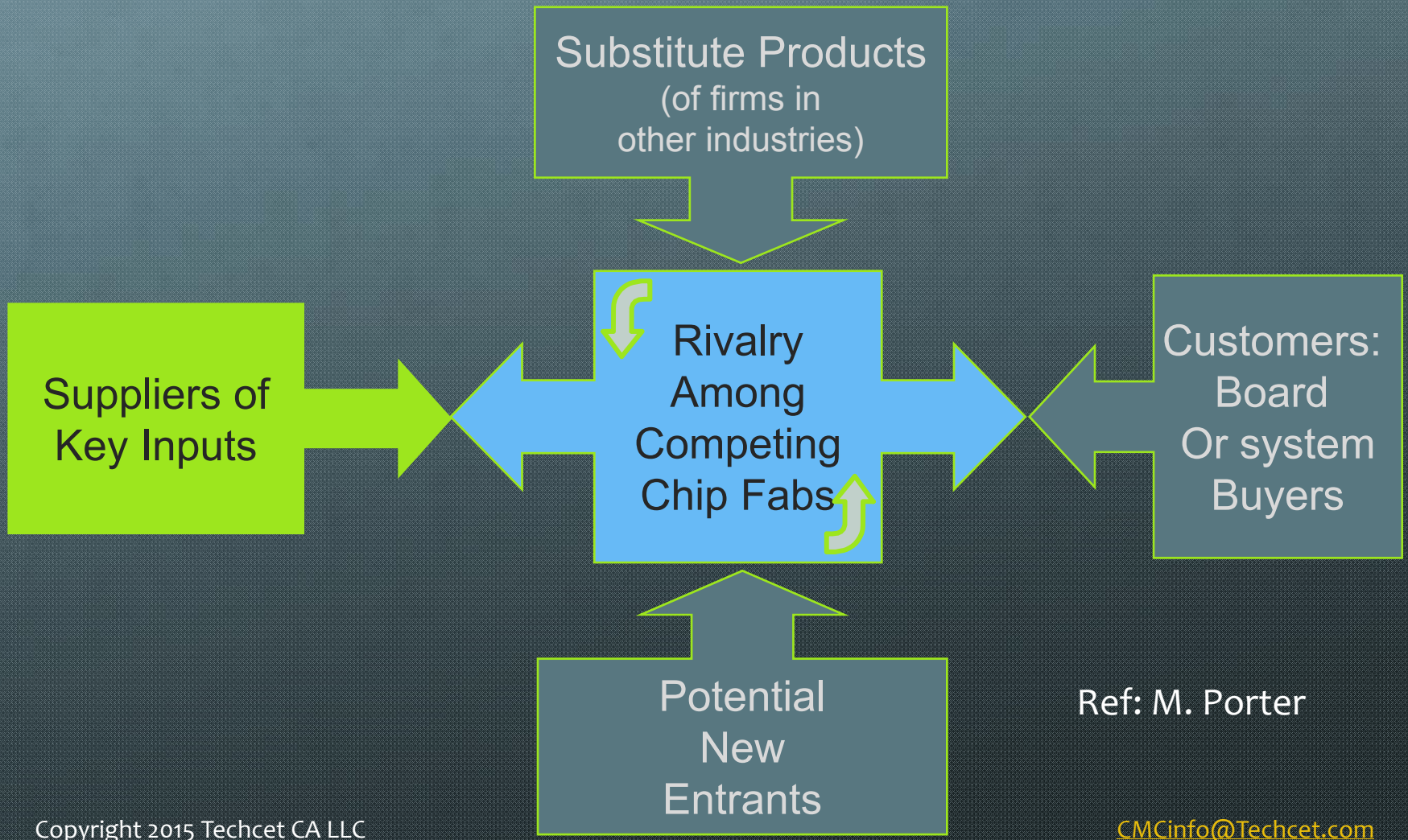
Introduction
5 Forces - Chip Fabs



Ref: M. Porter

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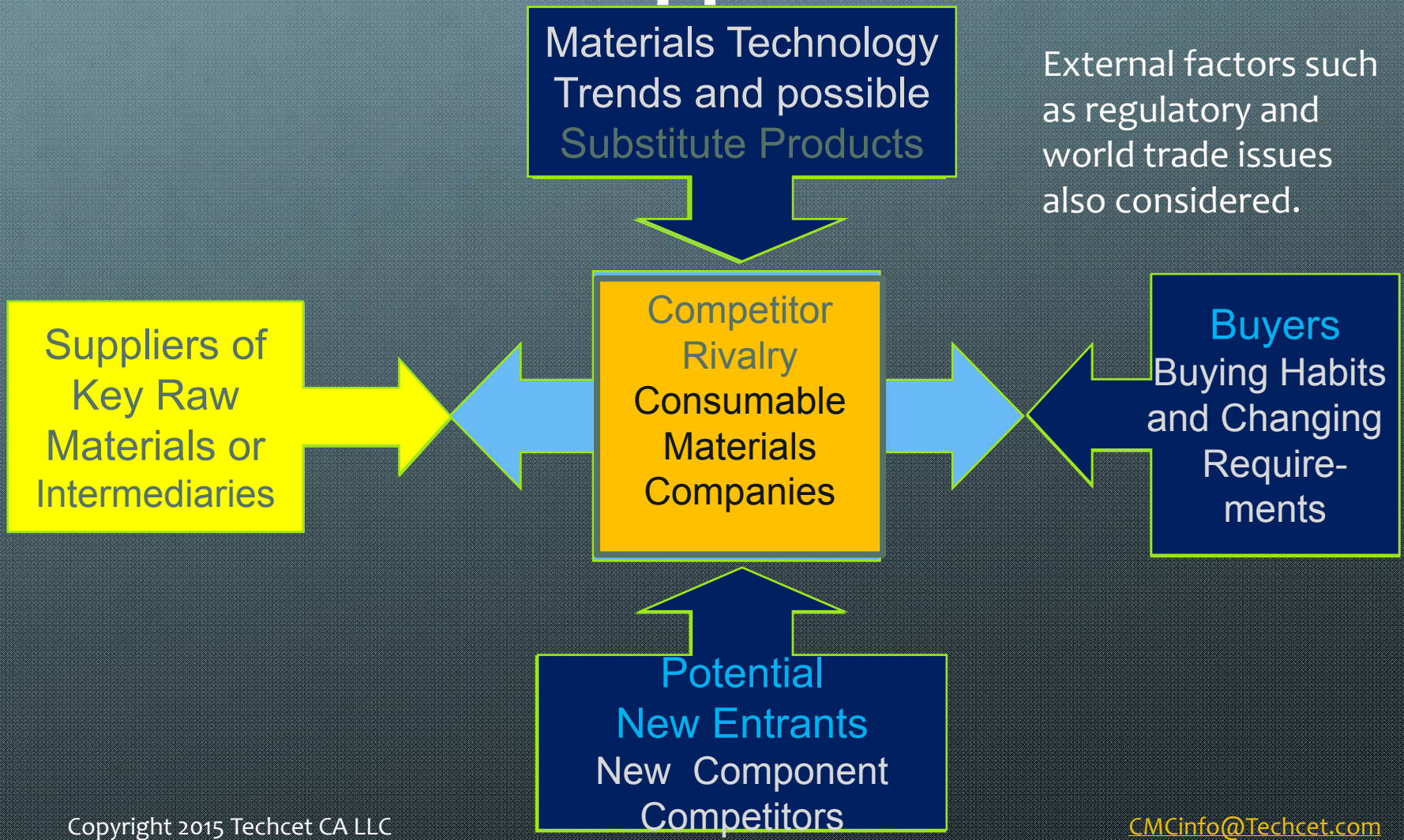
Introduction
Techcet Analyses 5+ Forces of Material Suppliers



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Introduction to Techcet Material Expertise

- Wet Chemicals
- CMP Consumables
  - Slurries / Abrasives
  - Pads / Conditioners
- Electronic Gases
- Photoresists
- Sputtering Targets
- Dielectric Precursors
- Silicon Wafers
- Poly Silicon
- Equipment Consumables
  - Quartz
  - Graphite
  - Silicon Carbide
  - Ceramics
  - CMP Parts
- ALD / CVD Metal Precursors
- Packaging Materials

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Semiconductor Market Overview

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Semiconductor Market Overview Highlights

- Semiconductor Market Revenues Growing 8%-9% over the past year and expected to grow 3-5% in 2015. Growth is driven by continued growth of cellphone and other mobile devices
  - Mobile devices drive need for smaller devices with increased capability, i.e. 3D NAND, FINFET Memory and Logic devices growing >15%.
- IoT growth fueling 200mm growth – MEMs expected to grow >20%/yr.
- Consumable Materials being constrained by China's share on raw materials and impacted by political issues in the Ukraine.
- Helium supply stable at present but is expected to be a concern as we approach 2021.

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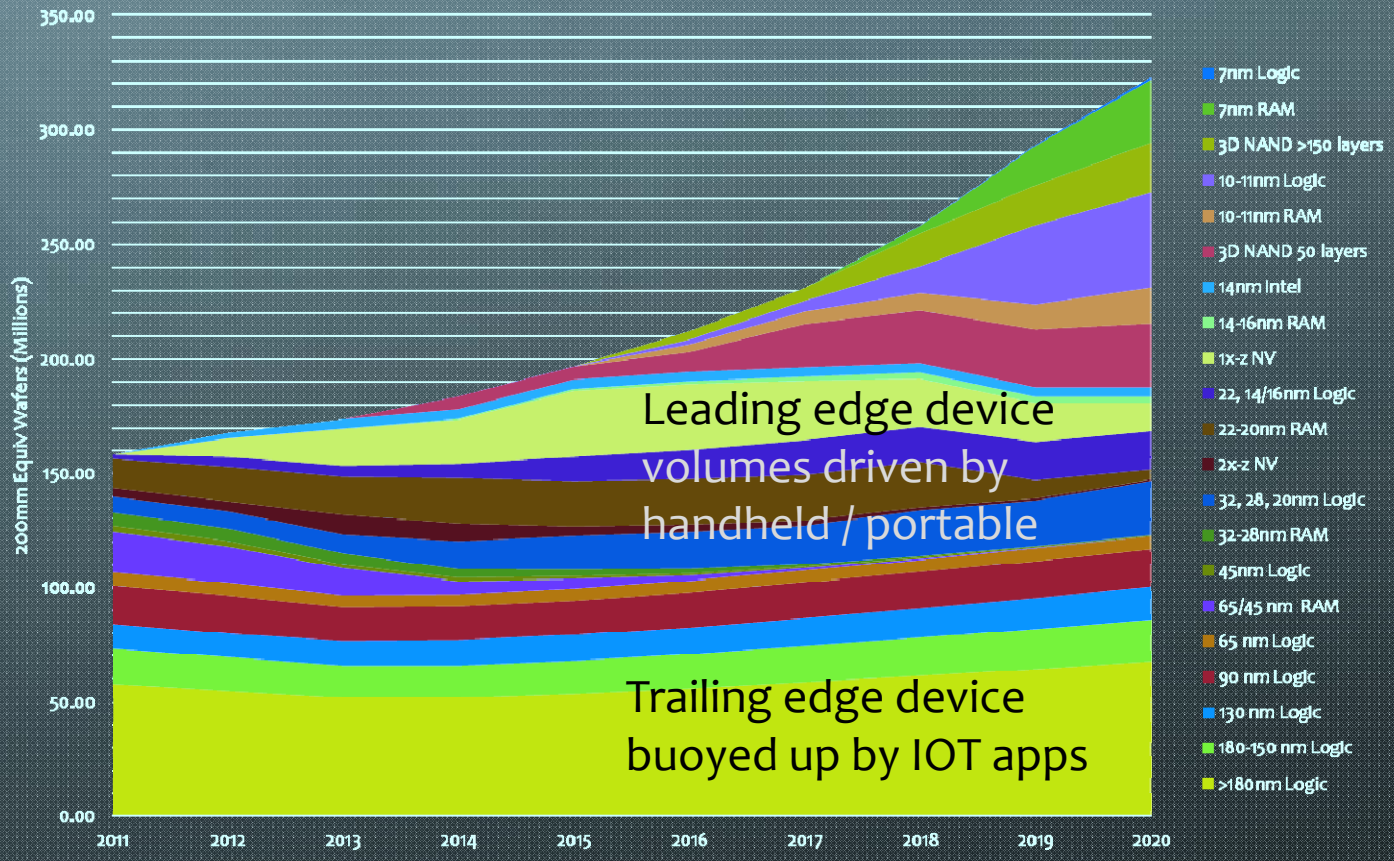
Semiconductor Market Overview
Device Production Forecast



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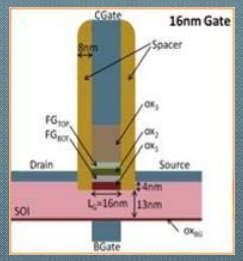
The Leading Edge - IC Technology Evolutions/Revolutions

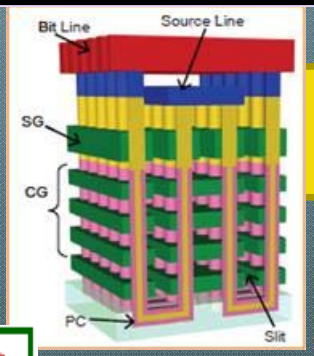
Note "Node" is "nm" performance, physical is GLph

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



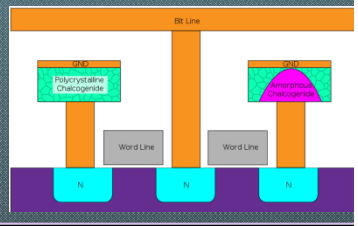
Non-Volatile 80-30nm features
3D NAND (BiCS, TCAT, etc.)

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

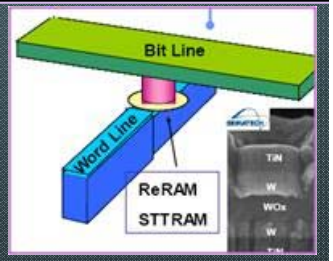


3D/V-NAND Extend for 5+ yrs with
16 to 256 layers

Non-Volatile <10nm
CNT? PCM



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



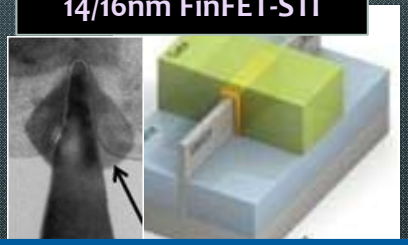
DRAM 32-28nm
Vertical Capacitors

DRAM
26-16nm
HκMG +
Si Fin

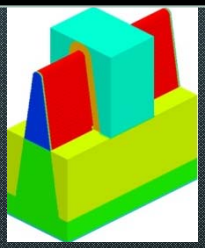
Continue DRAM Shrink w/ MPU

20nm Planar SOI
Hκ/MG

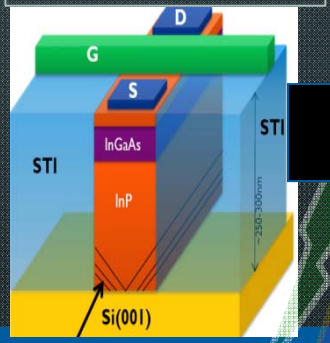
14nm TriGate
14/16nm FinFET-STI



10nm
Fin w/ STI, channel
change?



7nm
III-V or Ge ?



EUV
7nm ?

450mm
7nm?

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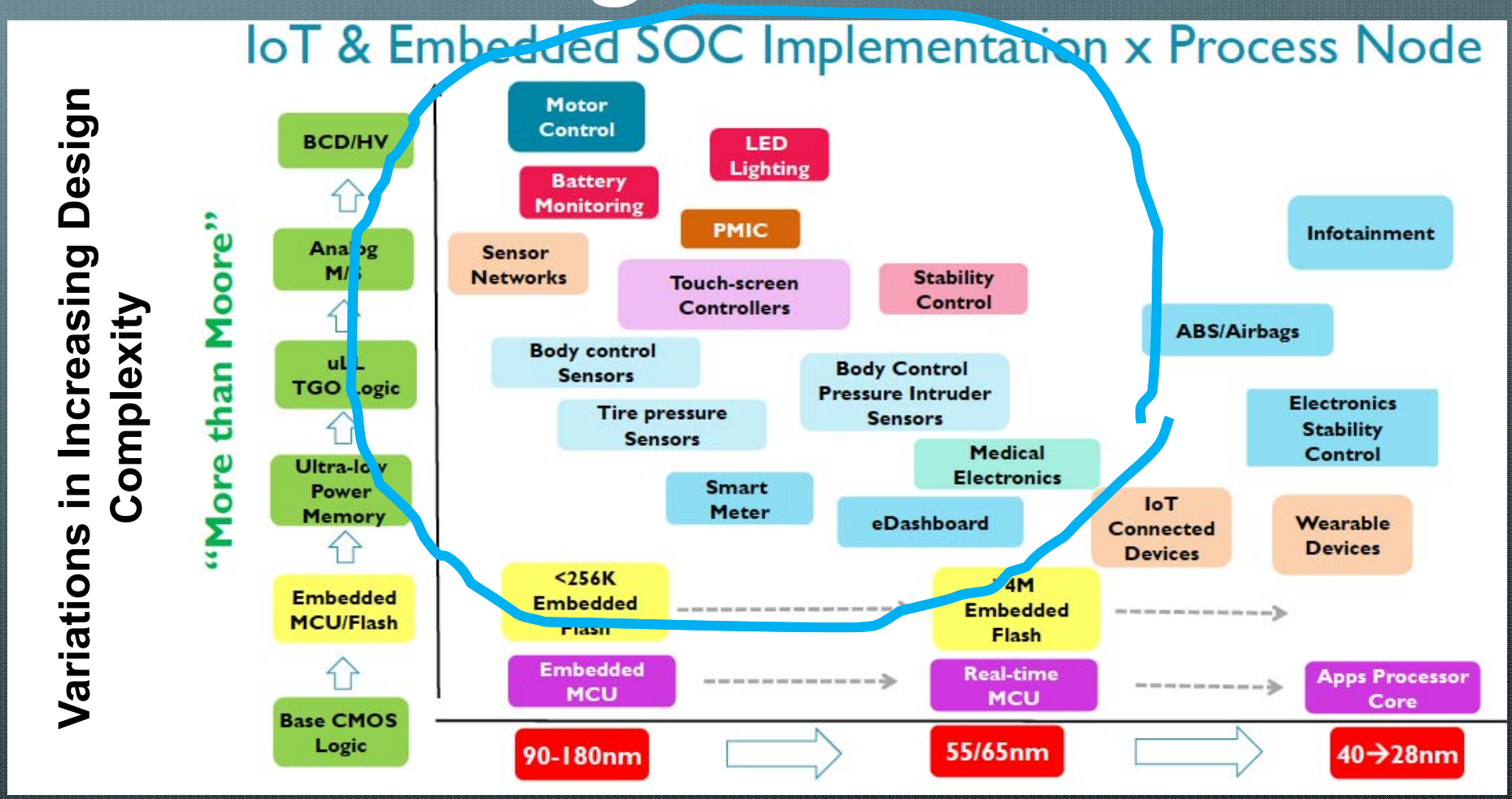
2013 — 2014 — 2015 — 2016 — 2017 — 2018 — 2019

Semiconductor Market Overview
IoT Fueling 200mm Growth



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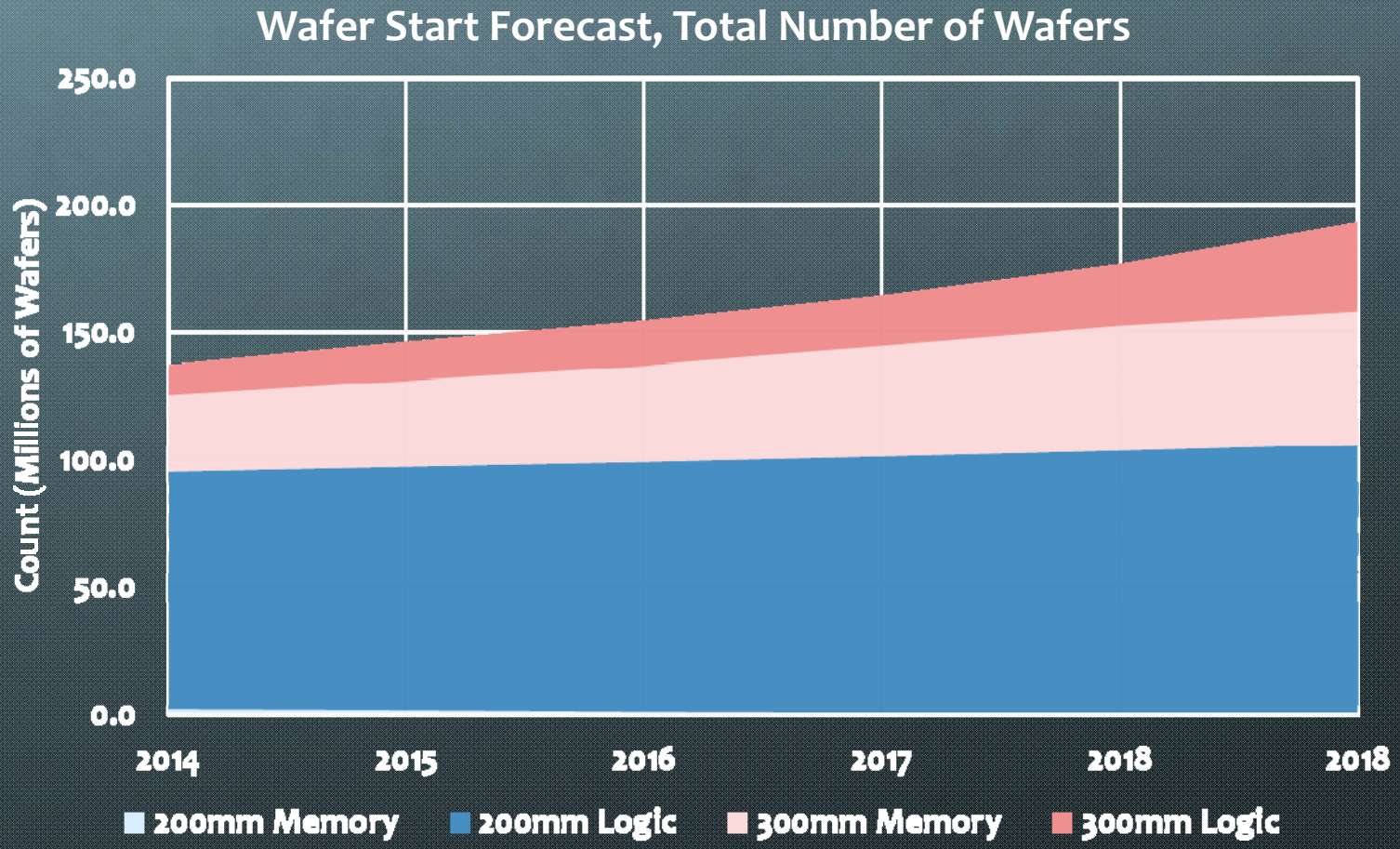
Source: ARM

Semiconductor Market Overview
Wafer Start Forecast



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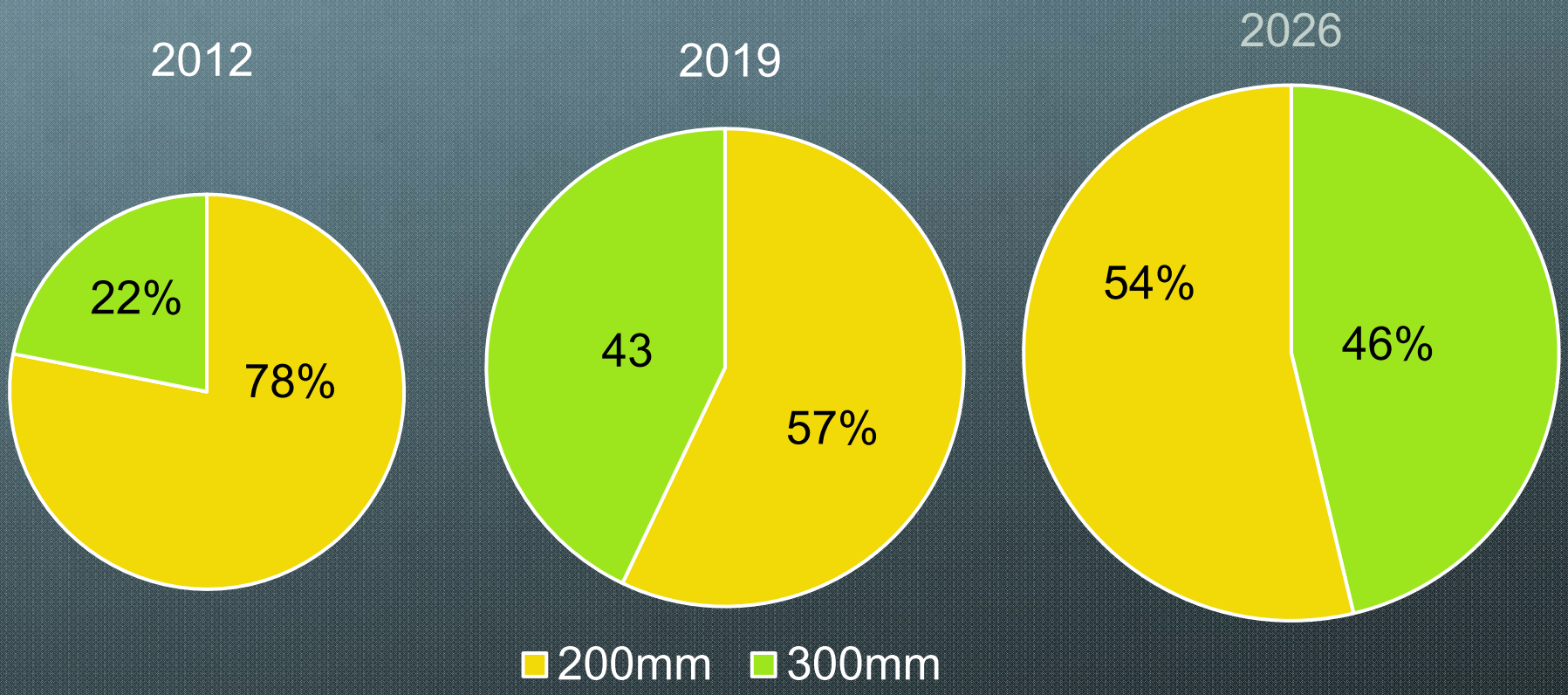
Semiconductor Market Overview
200mm Sustainability



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Semiconductor Market Overview
Forecast Trend Summary

- 200mm
  - Trailing-edge device manufacturing IS NOT expected to become obsolete though forecast period.
  - Growth in existing applications (MEMS, Signal Processing) and the emergence of Internet of Things (IoT) will sustain 200mm at a CAGR of 2.2% through market period.
- 300mm
  - 300mm wafer production forecast to increase at a CAGR of 15.1% through 2019, driven primarily by memory in outlying years.
  - Multiple processing layers associated with advanced node logic devices and 3D memory will further drive PVD target consumption to growth rates greater than wafer production.
- 450mm
  - 450mm platform expected to enter production for 7nm logic devices sometime after 2020.

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Semiconductor Market Overview
Forecast Methodology

- Factors effecting the target materials supply chain and price outlooks were analyzed with respect to published geopolitical and global economic forecasts as well as from detailed surveys with raw material suppliers.
- Gas revenues were forecast using publicly available information and information from surveys and interviews.
- The Target forecast was developed with respect to the following:
  - Supply chain factors impacting raw material prices
  - Impact of External and Internal Factors and their impact on the cost drivers of materials
  - Competitive environment among suppliers
- The 2014 market demand data and price expectations were input into Techcet's proprietary Wafer Pass Forecast™ to determine 5-year market revenues

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Electronic Gases Report Highlights

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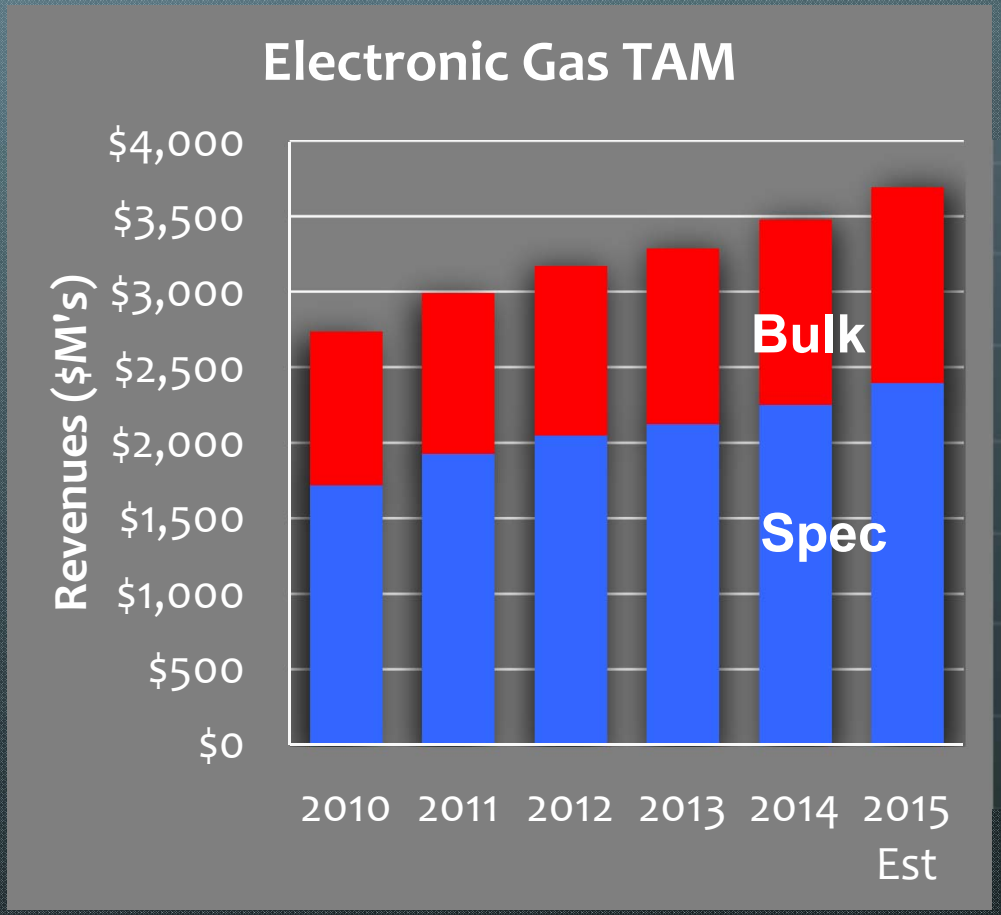
Electronic Gas Market

- Electronic gas market has grown 6% on average over the past 5 years
- Supply of various gases that are already problematic may be impacted further by growth in IoT applications, i.e. WF6, NF3, He



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Electronic Gas
WF6 Shortage

- NAND Flash market growth increasing demand for WF6
- Demand is outpacing supply as no new capacity has been added in recent years.
  - Reinvestment economics poor due to low pricing
- Current capacity in the range of 1,000-1,200MT
- ASP range from $70-150/kg based on volume/region
  - Asian market continues to be lowest price region
- Ammonium Paratungstate pricing saw slight decline in 2014 from China – raw material for tungsten powder
  - Expected to increase again in 2015 further impacting economics

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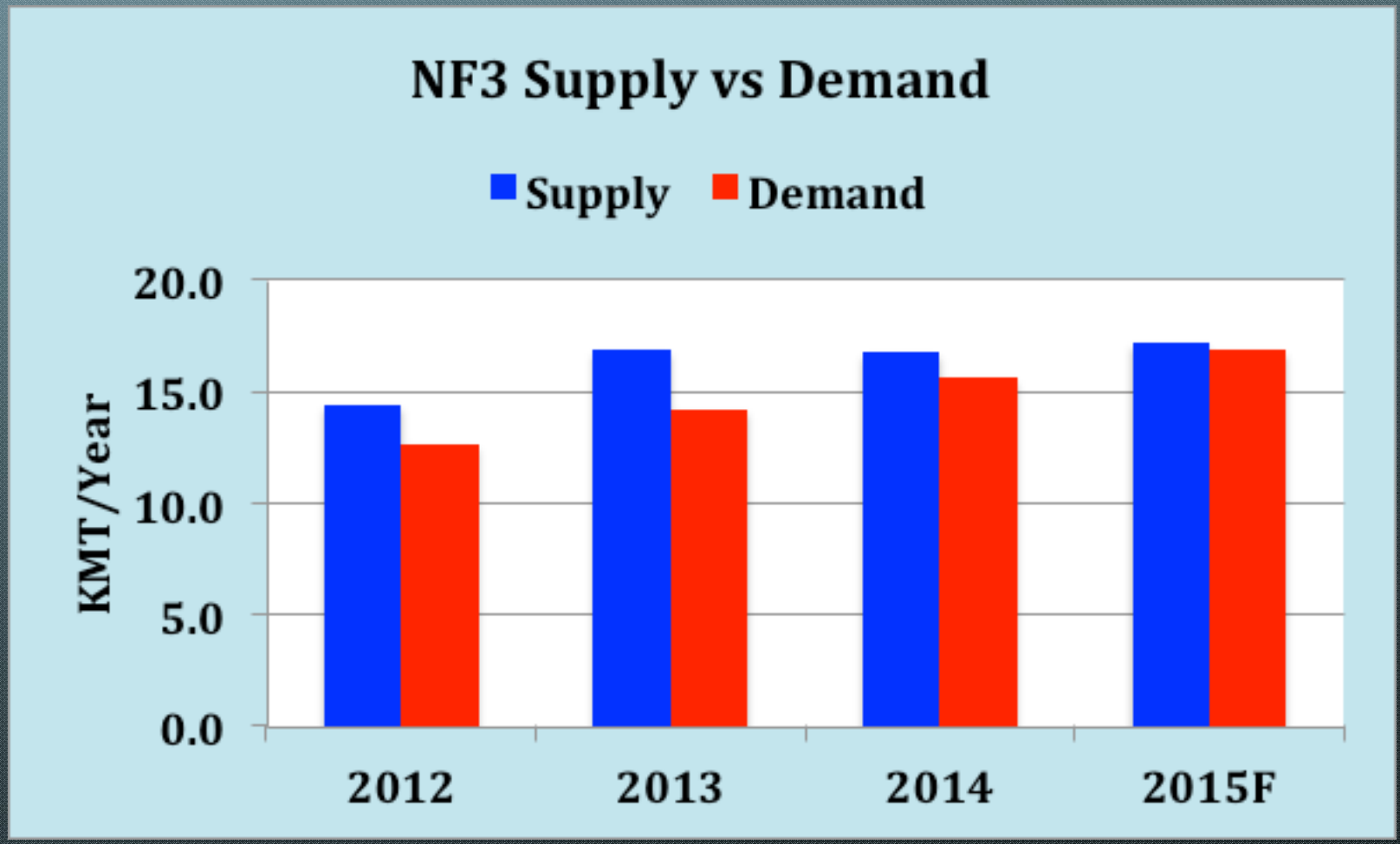
Electronic Gas
NF3 Market



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Electronic Gas
NF3 Balance

- NF3 demand increased 10.5% over 2013 from both semiconductor and LCD manufacturing needs, LCD represents around 45% of total usage
- 1,500MT of annual capacity removed from market due to plant shutdowns citing economic reasons
  - OCI (900MT) and Foosung (600MT)
- Supply and Demand close to balance with no new capacity expansions announced – again poor reinvestment economics due to pricing
- OCI, Air Products, and Kanto Denka remain the top three manufacturers with almost 75% of worldwide supply.
- IoT will push up demand slightly, yet this may be enough to cause availability problems over the next few years.
- Companies are hesitant to invest in more capacity.

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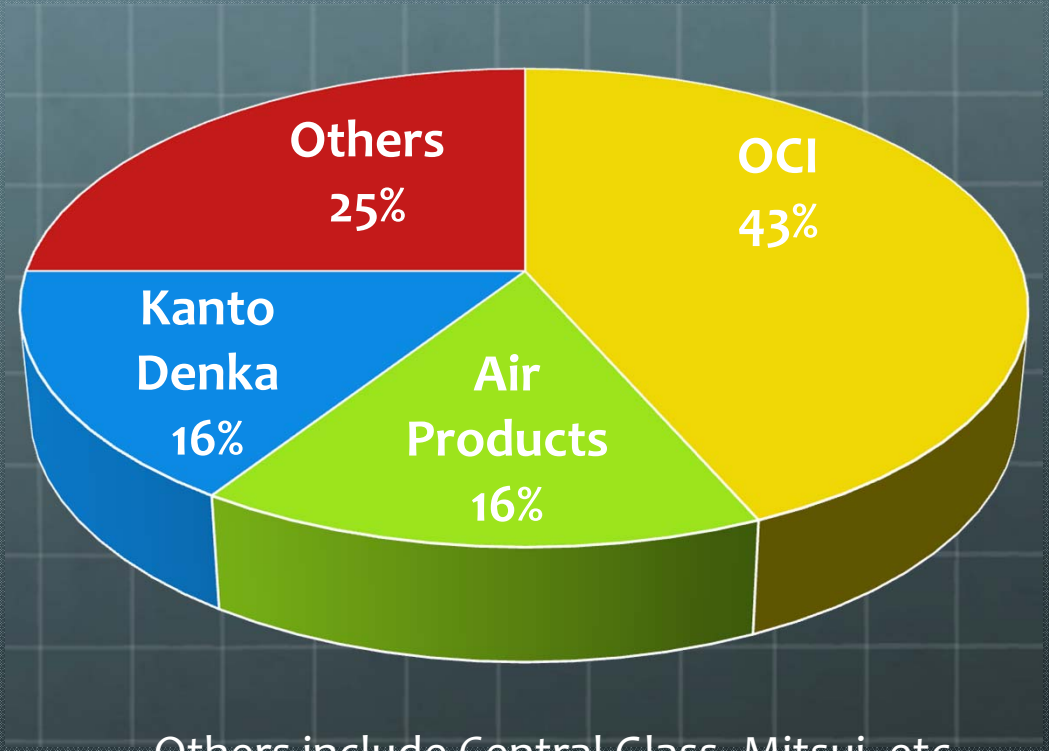
Electronic Gas NF3 Production



Others include Central Glass, Mitsui, etc.

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Electronic Gas Fluorspar Concerns

- Demand increasing across several industries causing concern over future shortages – key ingredient for making HF which is used to make fluorine gas used to produce many semiconductor gases
- Fluorspar production in 2013 was 6.7 million MT while demand was 6.5 million MT.
- Currently China provides 64% of worldwide supply but they only have 10% of the Fluorspar reserves
  - Depleting reserves, China has been reducing export annually since 2000, soon will become net importer, increasing shortage concerns
- European Commission classified fluorspar as one of fourteen critical raw materials in 2010
  - US considers it a Strategic Mineral

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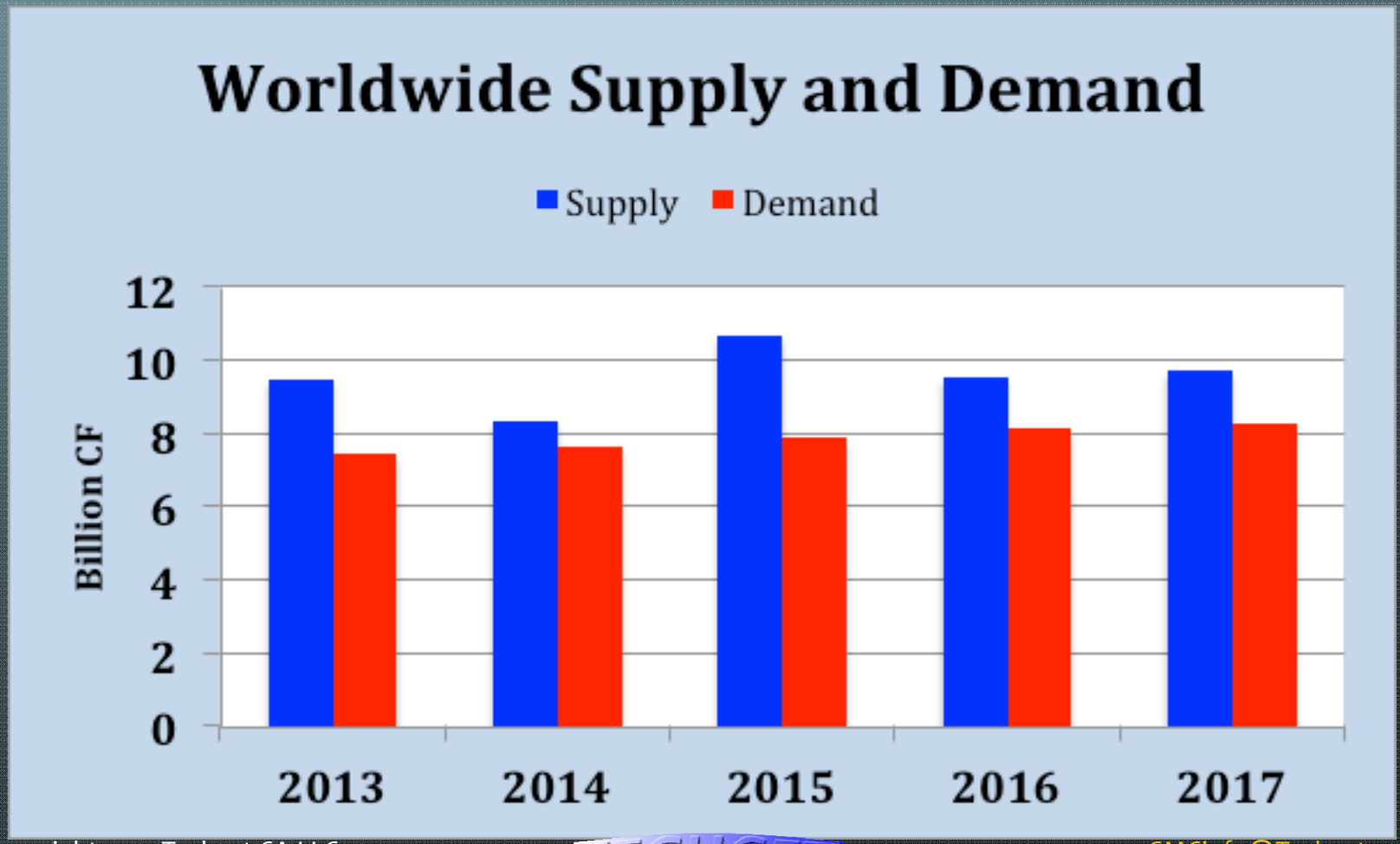
Electronic Gas Helium Market



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Electronic Gas
Helium Supply, Demand & Availability

- Stability and over-supply returned to the helium business in 2014
  - Big Piney joint project between Air Products and Matheson in Wyoming = add 200MSCF of additional capacity with expansion doubling to 400MSCF at the end of the last year.
  - Helium 2 plant in Doha, Qatar at the end of 2013. Qatar annual production = 1.96BSCF per year
- Annual Consumption growth traditional 3% per year has fallen to 1% per year
- The situation is expected to remain in an oversupply situation until 2017. Beyond 2017 supply may once again become tight unless more expansions are put in place.
- In 2021, BLM reserves will be taken off the commercial market as their supply is reduced to 3BCF and will be limited to federal and research requirements only.
  - The BLM currently represents 30-40% of the US supply and 15-20% of the worldwide supply.
  - Any new sources will take 3-5 years to cultivate and harness, thus work needs to start now to prevent a significant impact to the global helium supply in 2021.

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Electronic Gas
Neon

- Supply and Demand of Ne running close to supply.
- ~70% of the total neon output comes from within Ukraine and Russia.
- Shortage situation will continue into 2015 and maybe 2016. No significant added capacity planned .
- Current utilization rates are over 90% and will get higher as demand continues to increase. Plant disruptions are likely, as a result of running at such high utilization rates
- Political unrest in the Ukraine and Russia has tilted the balance of supply and demand, impacting availability.

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Electronic Gas
Xenon

- Xenon availability is expected to be worse.
- Demand is expected to exceed supply over the next couple of years until companies, such as Iceblick, are able to get new capacity online.
- Demand is currently estimated to be >10% higher than supply.
- As a result, prices for both these gases are expected to increase over the next couple of years.

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Sputtering Target Report Highlights

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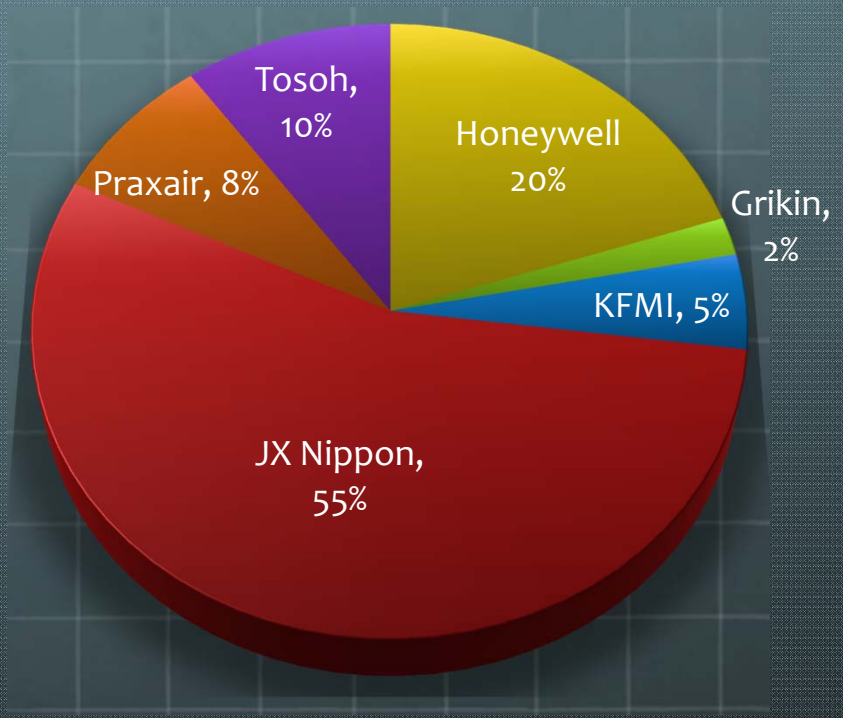
Sputtering Target Market Summary
2014 Supplier Market Share

Figure 8.1: 2014 Supplier Market Share



- *Penetration of Chinese supplier has reduced pricing and captured share, especially in Al targets for trailing edge devices.*
- *Chinese share gain primarily taken from Praxair and Tosoh.*
- *JX Nippon and Honeywell secured market share from their prominence in 300mm Ti and Ta targets for leading edge applications.*
- **Expect KFMI to increase market share during the forecast period.**

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Sputtering Target Market Summary
Target Production

Figure 8.2a: 2014 Sputtering Target Unit Production (% of Total Production)

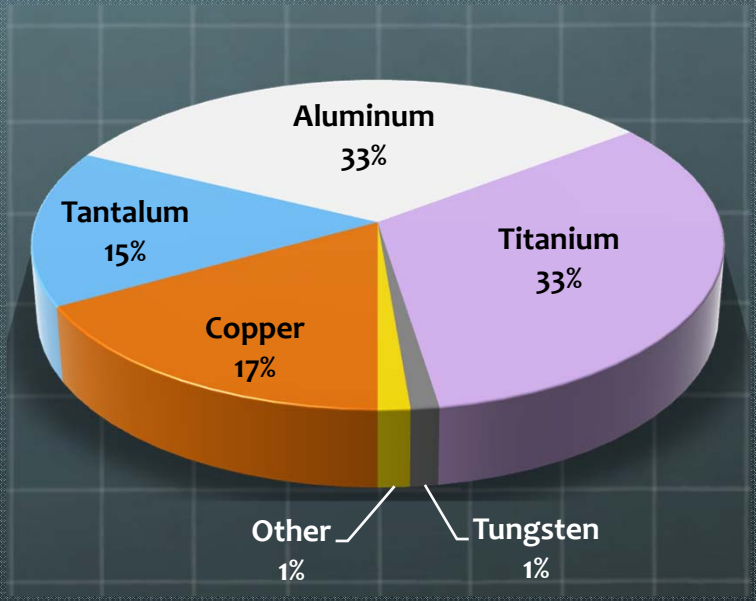
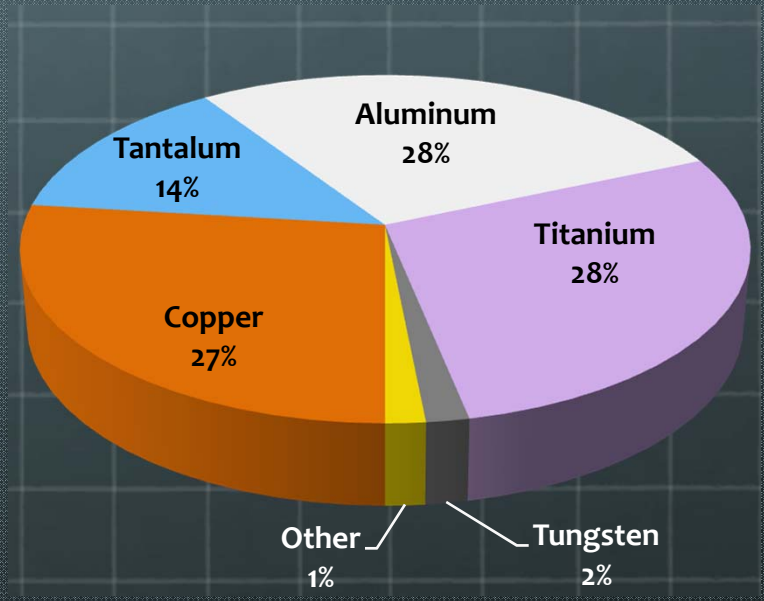


Figure 8.2b: 2019 Forecast Sputtering Target Unit Production (% of Total Production)



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Sputtering Target Market Summary Competitive Environment

- With expansion of semiconductor manufacturing in China, Chinese sputtering target manufacturers are expected to quickly gain greater market presence and compete for global market share.
- Target materials with the lowest manufacturing barriers to competition are most exposed to supply new entrants. Targets listed in order of competition and price pressures
  1. Aluminum
  2. Titanium
  3. Copper
  4. Other Materials
  5. Tungsten
  6. Tantalum

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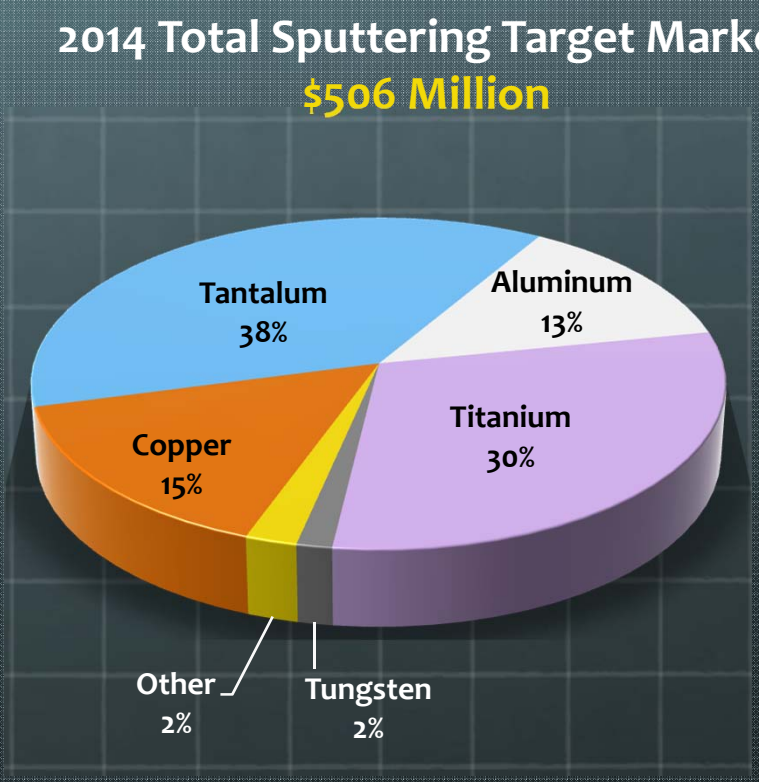
Sputtering Target Market Summary
2014 Target Market Revenue

- The total market for sputtering targets in 2014 was $506 million, a 3.8% increase from the adjusted 2013 revenue of $488 million.
- Revenue growth was tempered by average price reductions in Ta and Al and level prices in Cu and Ti.
- Tantalum is the leading target revenue generator due it's high intrinsic cost and selling price.
- The relatively high fractional revenue of Other targets partially accounted for by precious metals.



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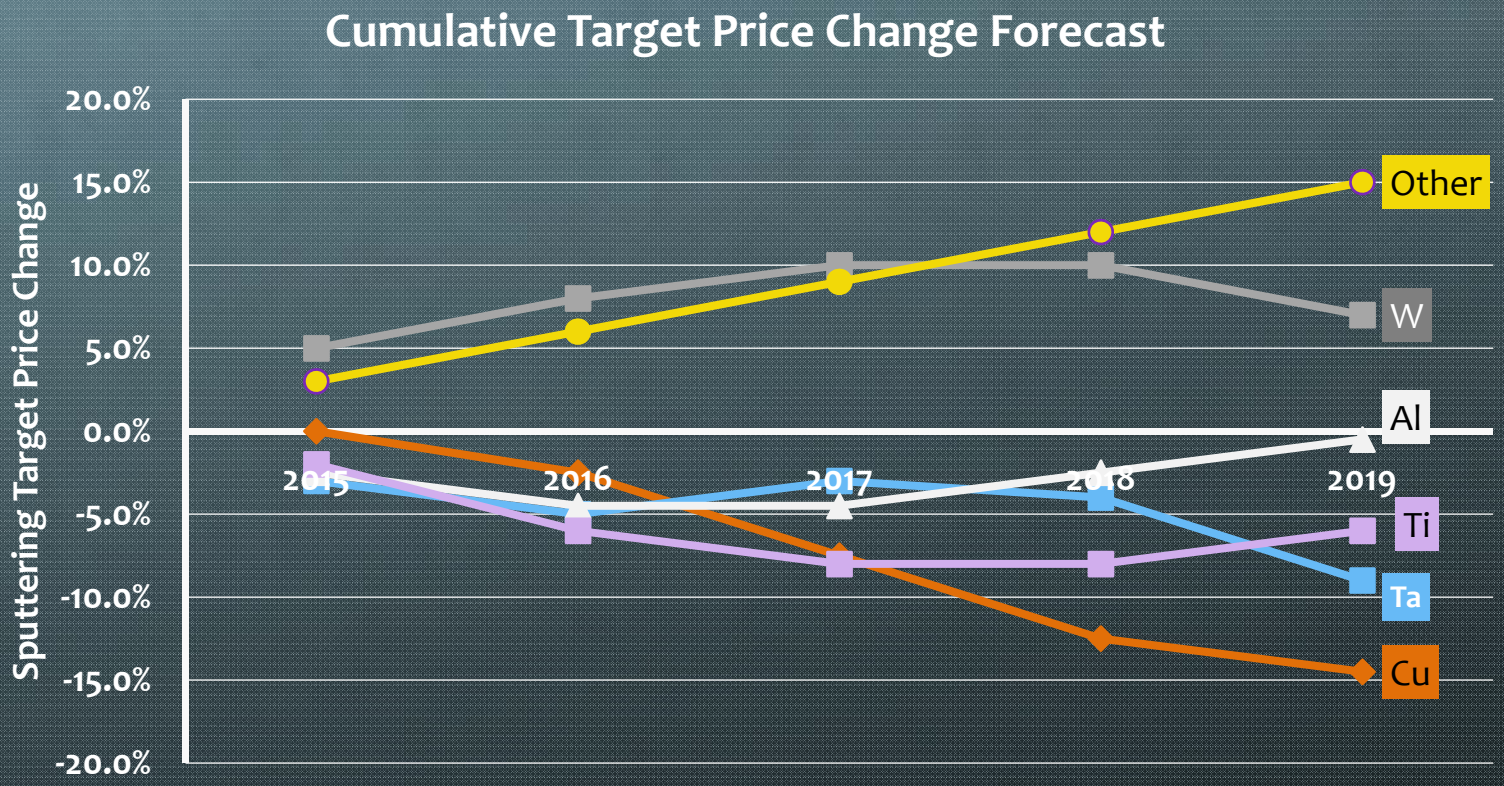
Sputtering Target Market Summary
Cumulative Target Price Forecast



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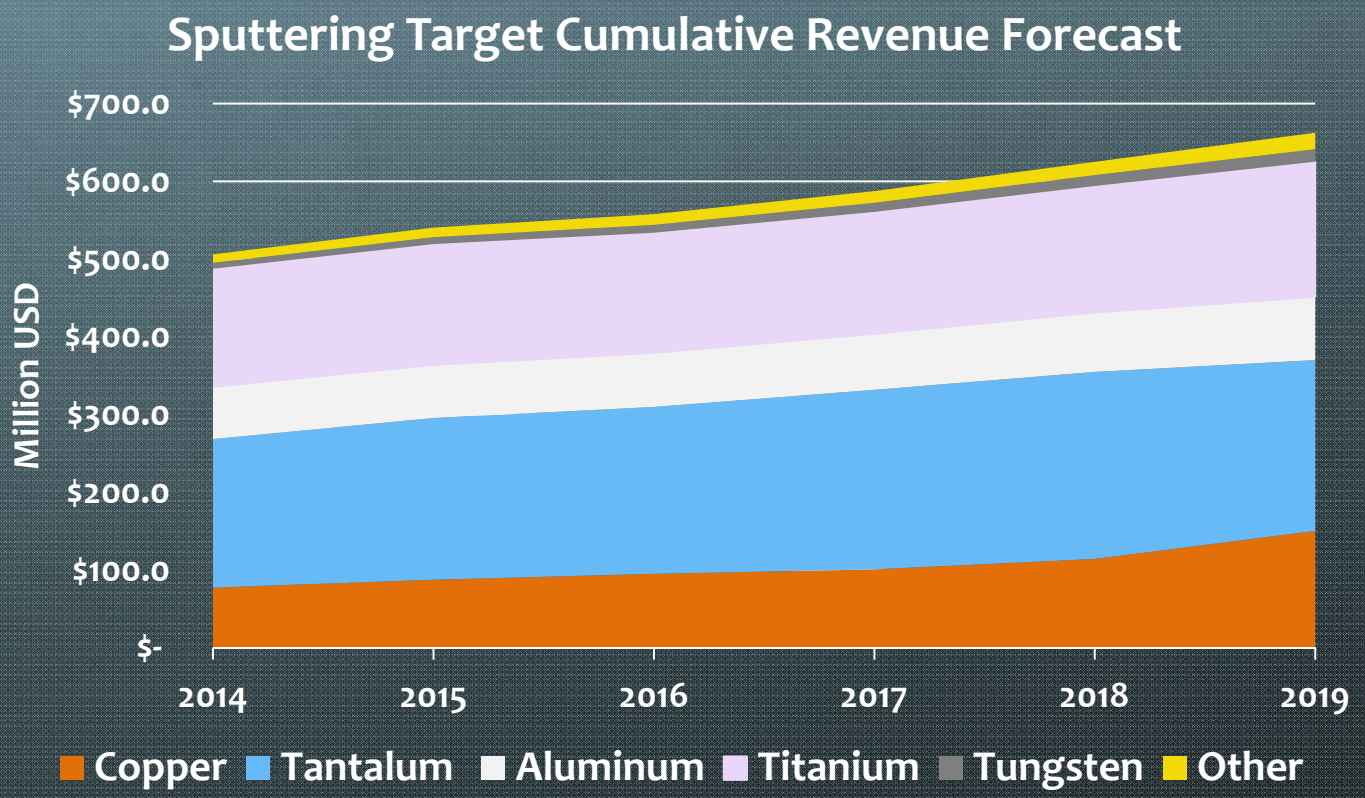
Sputtering Target Market Summary Cumulative Revenue Forecast



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Regulatory Updates

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Regulatory Updates
Helium Stewardship Act

- Responsible Helium Administration and Stewardship Act was passed by congress and signed into law in October 2013
  - Allows federal government to sell BLM helium reserves to the price sector preventing shortages, at least through 2021
- First public auction held in July 2014 with thirteen participants, resulting in two winners
  - 92 million SCF sold to Air Products and Praxair
    - 10% of the helium production from BLM
  - Next auction will take place in July 2015 and volume will increase to 25% of production
- BLM already advising industry to look for new sources beyond 2021, the current date BLM reserves will stop being auctioned

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Regulatory Updates
Copper *Constraints on Supply?*

- The ICSG has identified potential obstacles that could prevent additional Cu mines from coming on-stream, which include
  - Declining ore grades in developed regions such as US and Chile
  - Capital Risks: lower capital expenditures and operational cost escalation amid prolong recession and market volatility
  - Resource Availability: water supply issues, especially in dry mining districts
  - Energy Regulation: coal is the common source of electricity for mining and processor operations and in the future this source of energy may be limited due to environmental regulations.
  - Environmental Concerns: increasing government red-tape and vocal resistance from community
  - Political Risks: security and transport issues relating to crossing national borders
  - Labor: continued access to skilled labor is questionable
  - Currency Risk: currency strength of producer affected by difference between domestic input costs and imported inputs

Ref: International Copper Study Group, 2014

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Regulatory Updates
Tantalum *Closed Market Economics*

- **Per TIC:** It is important to understand that there are no official prices for tantalum or niobium commodities, as these metals are not traded on any metal exchange (London Metal Exchange or other). The price is determined solely by negotiation between buyer and seller.
- Price information reported by subscription-based resources often reflect spot purchases or small quantities, and reflect trends more than absolute valuations.
- Internal-generated "scrap" for recycle is considered as a raw material for primary processing reporting (such as ores, concentrates, and tin slags), while externally purchased scrap is deemed a secondary raw material source. Balancing processor receipts and processor production should be done with care.

Ref: USGS Commodity Summary, January 2015
TIC Bulletin, December 2014

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Regulatory Updates
Titanium and *The Putin Problems*

- Russia's incursions into Eastern Ukraine and resulting economic sanctions from the West expected to disrupt Aerospace-grade Ti supply
  - Ukraine supplies almost all of the Ti concentrate to VSMPO production
  - VSMPO-Avisma is Russia's largest producer of Ti and supplies 30% for the titanium used by U.S. Aerospace manufacturers Boeing and United Technology
  - Sergei Chemezov, CEO of VSMPO's parent (Rostec State Corp.) is on the U.S. sanctions list
- Ukrainian Ti produced ZTMC seeking U.S. government financing to expand production and increase exports to the U.S.
- Boeing and UTI reportedly building 6 months of inventory of Russian-manufactured Ti components to hedge against disruption

Ref: Wall Street Journal, 7 Aug 2014
Naked Capitalism, 18 Sep 2014

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Regulatory Updates
Titanium and *The Putin Problems*

Enacting additional economic sanctions on Russia is NOT expected to impact the supply of semiconductor-grade titanium

- Dawne Hickton, CEO of RTI, reported confidence that US suppliers RTI and ATI could cover for any supply disruption
- Semiconductor-grade Ti supplied from US and Japanese suppliers
  - Toho Titanium, a subsidiary of Nippon Mining, supplies cored semi-grade Ti ingots exclusively to JX Nippon
  - Sumitomo offers cored semi-grade Ti ingots to market
  - Honeywell sources Ti sponge from their Salt Lake City operation to Fombell, PA for refinement into ultra-high purity Ti crystal

Ref: Roskill Consulting, 9 Oct 2014

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Supply Chain Updates
Tungsten *China Update*

- China had been controlling the global tungsten supply to maintain prices by
  - Restricting exploration, mining, and export licenses
  - Forbidding foreign investment
  - Enacting constraints on mining and processing
  - Imposing Export Taxes on tungsten materials
- WTO rules that China's export quotas on tungsten, molybdenum, and rare earth metals violate WTO policies. China vowed that export restrictions would be lifted and all WTO obligations be implemented by 2 May 2015.
- China expected to respond by strengthening regulation of tungsten production and distribution.
- New, globally disperse mines are currently in various stage of development as reported in Techcet's 2013 CMR for Sputtering Targets. Non-Chinese mines forecast to supply 9% of total tungsten demand by 2018.

Ref: www.wto.org
USGS Commodity Summary, January 2015

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Regulatory Updates
Dodd-Frank

- Requirement to certify Tantalum, Tin, Gold, and Tungsten used in manufacturing is not from the Democratic Republic of Congo
- US Dodd-Frank compliance becoming more streamlined with standardization but requires much manpower, time, and expense by US manufacturers
- New Republican led congress vows to repeal Dodd-Frank and has begun initial efforts with regulations impacting the financial sector.
- European Commission is debating implementation of similar or more stringent requirements for conflict minerals and this should be coming out later this year

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Report and Quarterly Meeting Schedule

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Techcet Critical Material Reports™ Report Offerings

	Techcet Critical Materials Report	Issue Date
1	2014 Silicon Equipment Parts	Jul 31
2	2015 Hi K / ALD Metal Precursors	Jul 31
3	2015 Dielectric Precursors (STI, Gapfill, Pattering, and Interlayer)	May 31
4	2015 3D/TSV Packaging Materials - Interposers	Aug 31
5	2015 3D/TSV Packaging Materials - Metals	Jul 31
6	2015 Wafer Level Packaging (WLP) Polymers	Available
7	2015 Sputtering Targets	Available
8	2015 Silicon Carbide	May 30
9	2015 Wet Process Chemicals	Mar 31
10	2015 CMP Slurries, Pads and Other Consumables	May 30
11	2015 Photoresists and Ancillaries	Jun 15
12	2015 Silicon Wafers	May 30
13	2015 Electronic Gases	Available
14	2015 Quartz	Jul 31

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Schedule Updates

Subject	Report Delivered	Update 1	Update 2	Update 3
Targets	Yes	Aug 2015	Nov 2015	Feb 2016
Gases	Yes	Aug 2015	Nov 2015	Feb 2016
CMP	May 30	Aug 2015	Nov 2015	Feb 2016
Wet Chem	Jun 10	Aug 2015	Nov 2015	Feb 2016
Silicon Wafers	May 30	Aug 2015	Nov 2015	Feb 2016

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Quarterly Meeting Schedule

	April	July	Nov	Feb 2016
Topics	Gases / Targets	Open	Open	Open

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Analysts Contact Names

- **For Info on Supply Chains, Email: CMCinfo@Techcet.com or call 520-977-5274**

Subject	Analyst
Targets	Chris Michaluk
Gases	Bruce Adams / Lita Shon-Roy
Wet Chemicals	Yu Bibby Ph.D. / Chris Blatt
CMP Consumables	Sue Davis / Karey Holland, Ph.D.
Silicon Wafers	Ralph Butler

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Wrap-up / Open Forum

Techcet's Material Expertise

- Wet Chemicals
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  - Slurries / Abrasives
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- Dielectric Precursors
- Silicon Wafers
- Poly Silicon
- Equipment Consumables
  - Quartz
  - Graphite
  - Silicon Carbide
  - Ceramics
  - CMP Parts
- ALD / CVD Precursors

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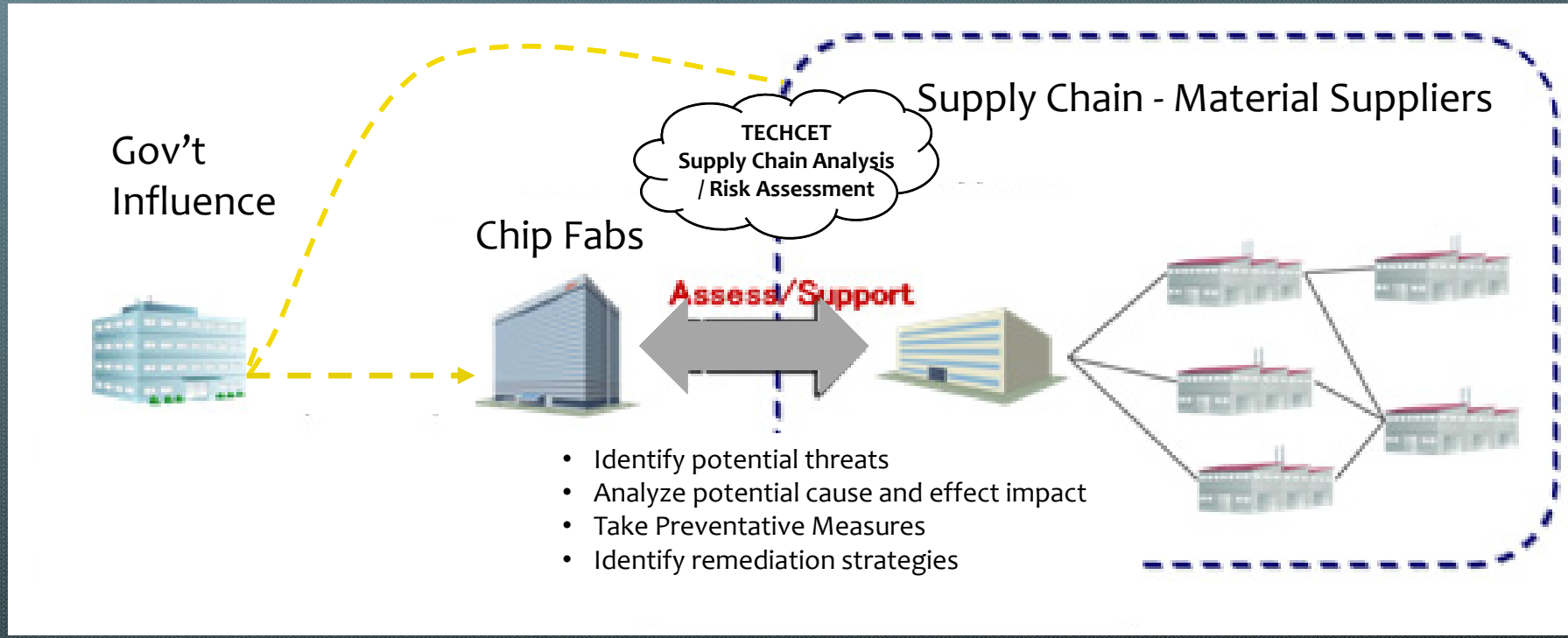
Techcet's Strategic Factor



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