

# New Perspectives in Semiconductors

cycles, geopolitics, technologies & outlooks



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# Who is TechInsights?

- World's Largest Reverse Engineering Firm
  - Everything sized from Angstroms to Audi's
  - Unmatched breadth knowledge of technology
  - 100's of employees with deep engineering experience
  - Based in Ottawa, Canada
    - With private equity backing
- With a vision to build the world's best technology information platform
  - Technology – Market Research – And More to Come
- Acquired VLSIresearch in 2021
  - “Because VLSI is the world's best in market research”
    - *Gavin Carter, CEO of TechInsights*
- *An explosive combination*
  - *Like Lava hitting the Sea*





# The Silicon Cycle

Has it moderated ... or not?



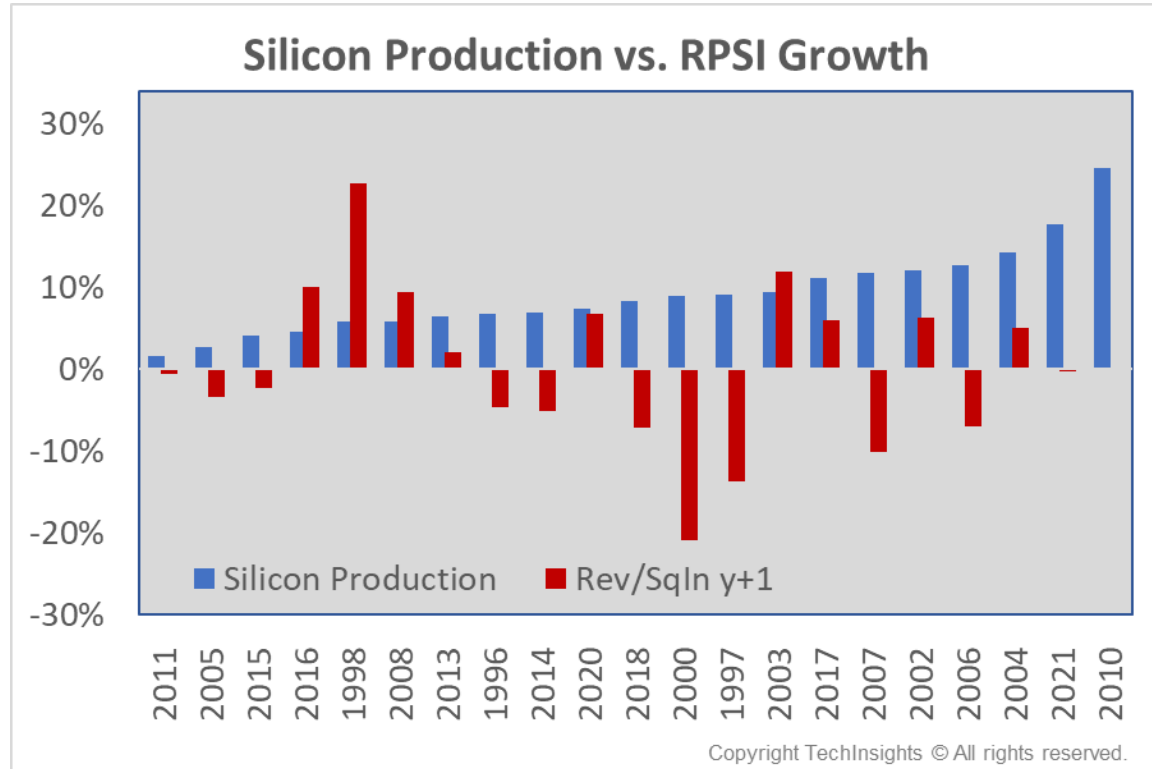
# Cliff Notes: The silicon cycle

- Demand side of cyclicity driven by Keynesian Acceleration Principle
  - Semiconductors follow 1<sup>st</sup> Derivative of the economy with weekly turns
  - Equipment follows 2<sup>nd</sup> Derivative
- Supply side driven by technology and lags
  - 2-3 years to build a fab
  - 2-3 years to ramp a node
    - + 2-3 years to develop process & tools
  - 2-3 years to design a chip for a new node
  - Christmas driven demand cycle



# What's supply got to do with it?

The rule that  
large  
production  
ramps precede  
downturns is  
questionable at  
best





# What's supply got to do with it?

- Supply is important, but it's only half the equation
- Demand is other half
- Plus, technology, government, and business model shifts can change all outcomes

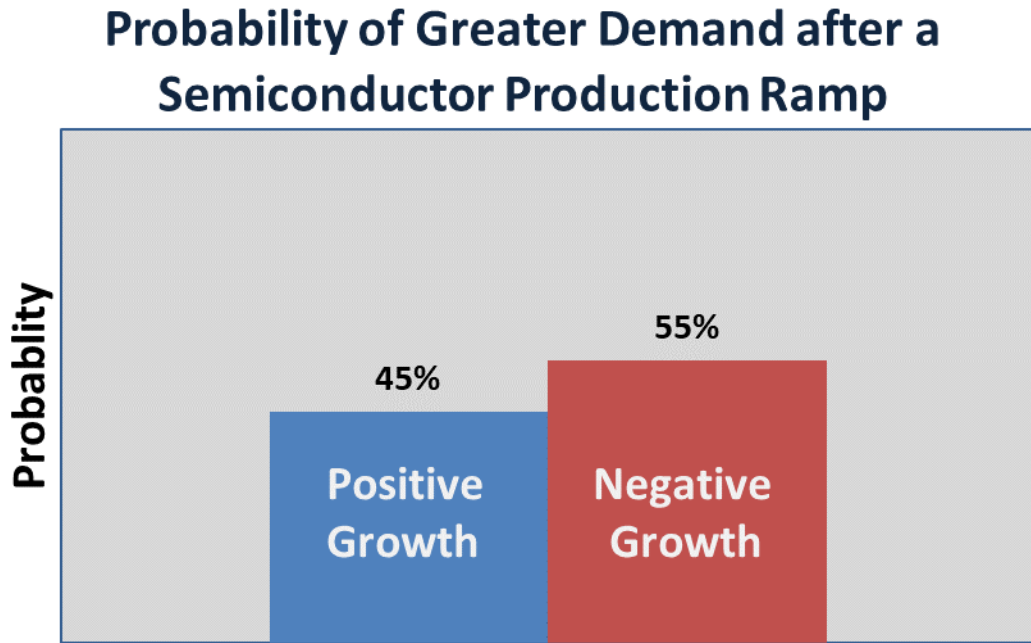
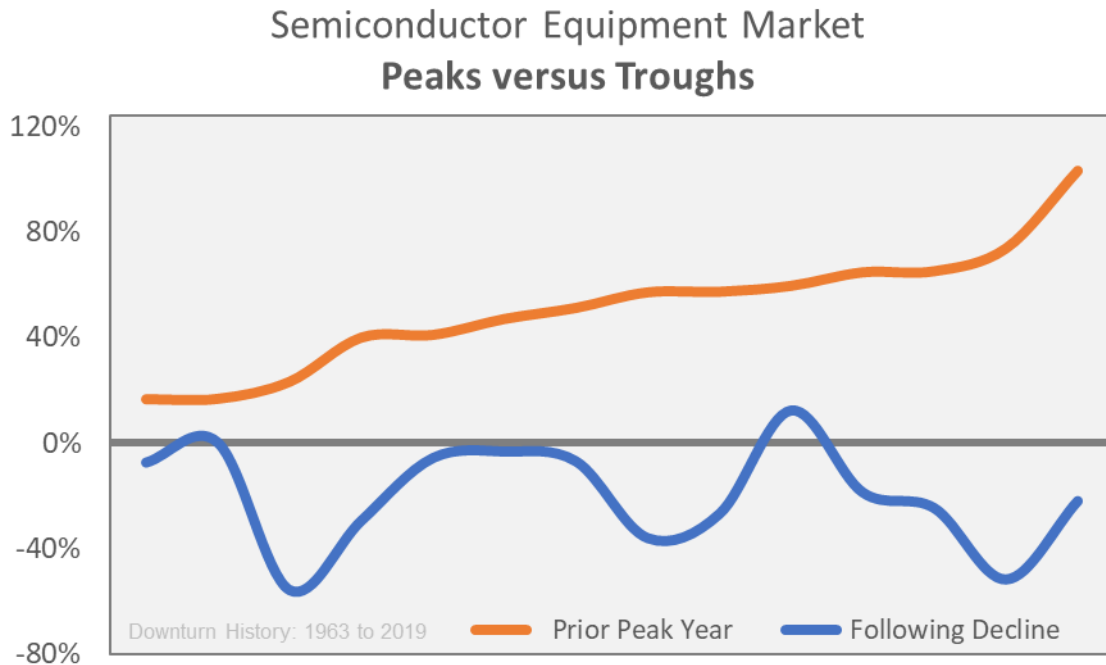


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# What's supply got to do with it?

The rule that large growth precedes big downturns is also questionable



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# Problem with stochastic forecasting

- Cycle has always been bimodal
- Forecasters tendency to chase means
  - Especially when it comes to downturns
  - With a tendency to project out of recent trends
- But if baselines are time and infrastructure dependent...
  - Chasing means is a fool's errand

	Total Decline				Prior Peak Year			
	Semi. Equip.	Semi.	Elec.	GDP WW PPP Basis Pt Change	Semi. Equip.	Semi.	Elec.	GDP WW PPP
Average of All	-21%	-8%	3%	-228	52%	28%	12%	7%
Average before 2000	-20%	-12%	5%	-213	58%	33%	12%	8%
Average 2000-2010	-38%	-12%	-4%	-350	49%	25%	12%	8%
Average after 2010	-10%	-4%	0%	-157	46%	18%	9%	6%

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# This Time it's Different!

## Every cycle is different



# Recession Years: 2012-13

- Business Drivers
  - 2011 Memory Slowing
- Emergent Technology Drivers
  - 22nm node
  - HKMG and finFET
  - Fab white-space expansion model
- Triggers
  - GDP Slows
    - 2011 U.S. Debt Ceiling Crisis
    - S&P lowers U.S. credit rating
  - Foundry miss on 28nm
  - Smartphone Commoditization

Total Decline			
Semi. Equip.	Semi.	Elec.	GDP WW PPP Basis Pt Change
-22%	-1%	3%	-136
Prior Peak Year			
Semi. Equip.	Semi.	Elec.	GDP WW PPP
103%	31%	19%	6%

# Recession Years: 2019

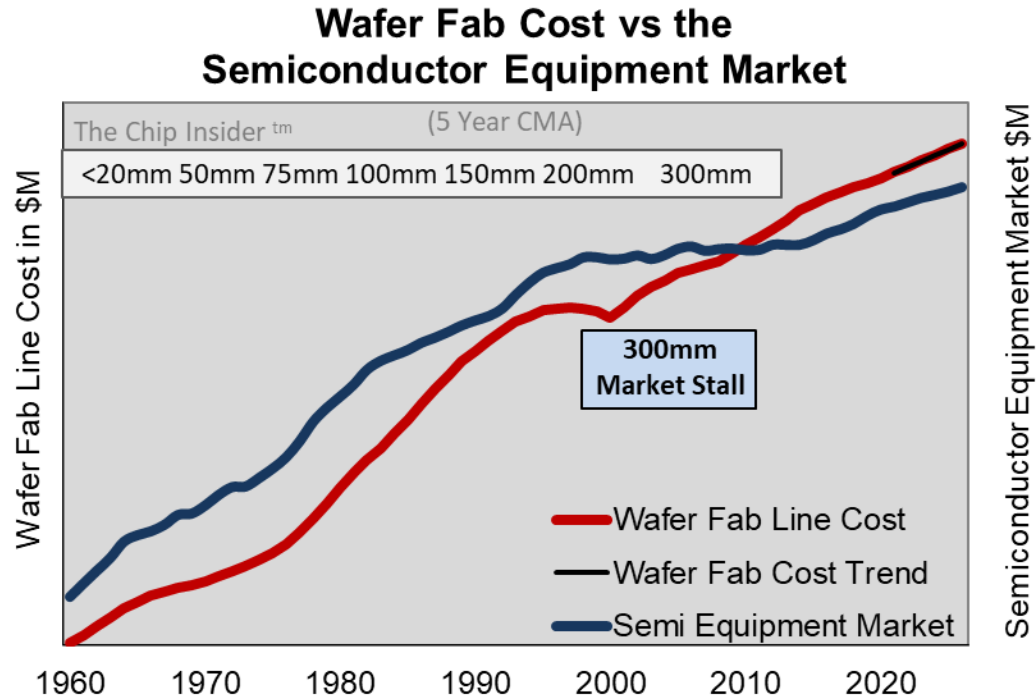
- Business Drivers
  - NAND Capacity transition
- Emergent Technology Drivers
  - HDD to SSD
  - Planar NAND to Vertical NAND
- Triggers
  - GDP Slows
  - Memory Capacity Glut

Total Decline			
Semi. Equip.	Semi.	Elec.	GDP WW PPP Basis Pt Change
-7%	-11%	-2%	-168
Prior Peak Year			
Semi. Equip.	Semi.	Elec.	GDP WW PPP
17%	14%	5%	6%

# Why Growth has Risen

## *off the 1995-2010 mesa*

- ***The Chip Insider***
  - February 19, 2021:
- “In 2003, the first 300mm fabs were coming on line and were far more productive than 200mm. That 1997 cost number for a 200mm equated to almost \$18-per-sq.cm., which was down to \$8 in 2003 and hit a bottom of \$5 in 2010.”



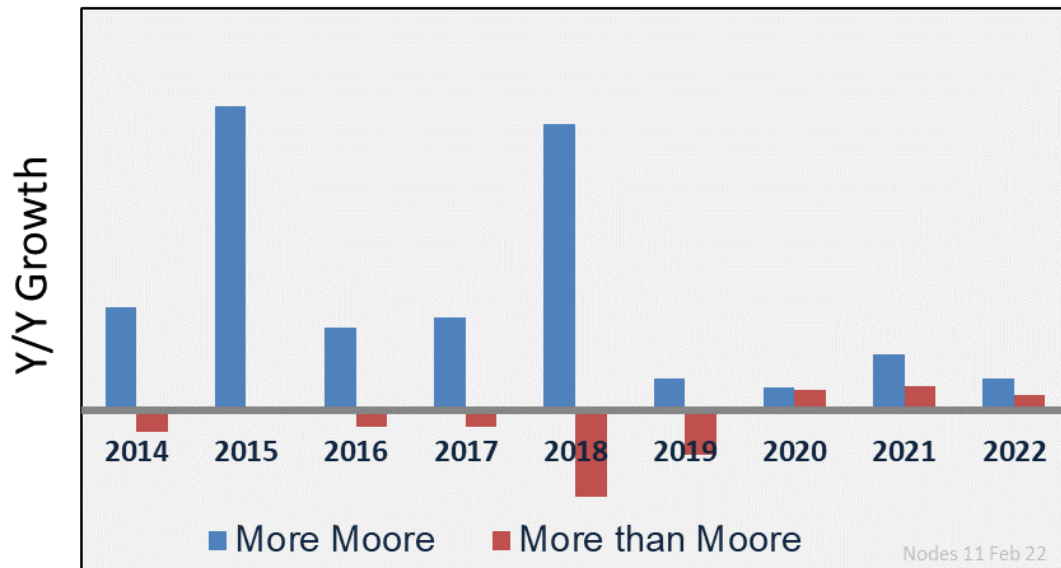
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# What's next?

- 200mm holiday is over
- More than Moore Capacity expansion is matching More Moore
  - Analog, Power, Chiplets
- More than Moore is no longer a friction source
- Discretes in the 90's: everything that could be integrated had been integrated

## Moore than Moore Capacity 200mm Holiday Ends in 2020



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# Market Outlook: *Billions are no longer cool...* *A only a Trillion Dollars is cool*





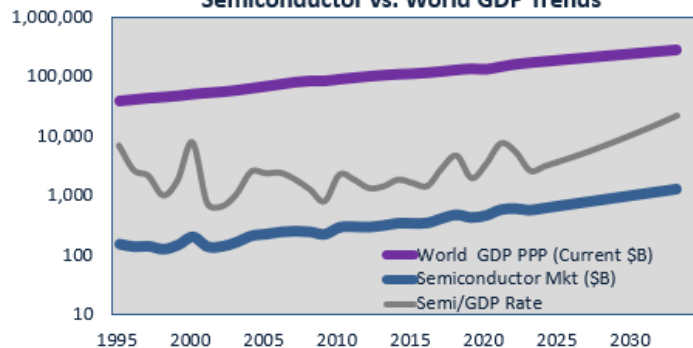
# Cliff Notes: Market Outlook

- **Innovation is exponential**
- **Software is Hardware** constrained for the foreseeable future
- **Semiconductors are no longer the rust belt of technology**
- **Average Long Term Growth Forecast**
  - **5% Electronics Market**
  - **7% IC Market**
  - **7% IC Equipment Market**
  - **5% Silicon Demand**

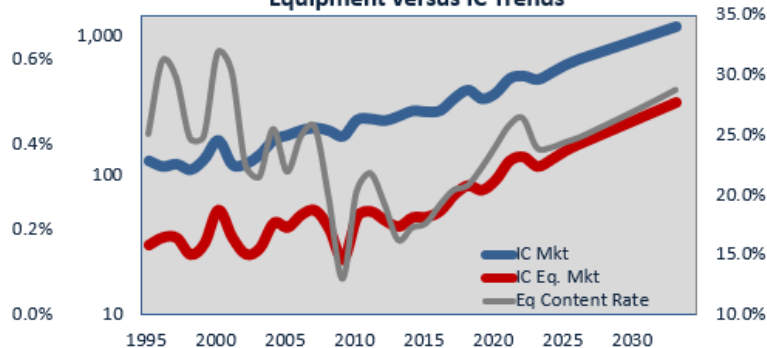


# Long-term Semiconductor Outlook

## Semiconductor vs. World GDP Trends



## Equipment versus IC Trends



## Decadal Trends

Where we'll be in 10 Years

\$ 283 T World GDP

\$ 1.3 T Semiconductors

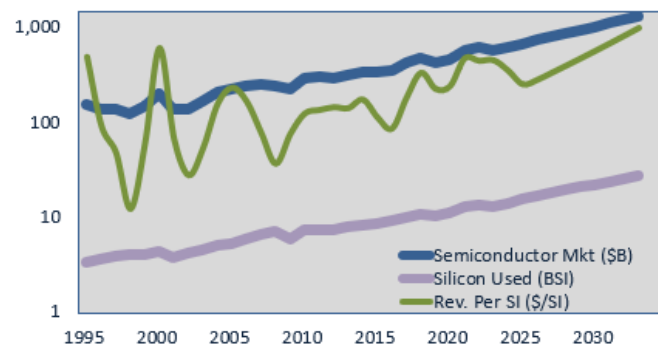
9% Chip AGR

0.47% IC Content

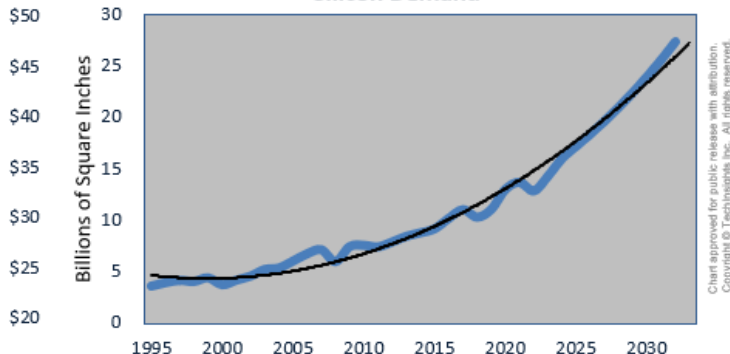
\$ 0.33 T Equipment

29% Eq Content

## Semiconductor versus Silicon Trends



## Silicon Demand



## Decadal Trends

Where we'll be in 10 Years

27 BSI Silicon

\$ 48 RPSI

1% RPSI AGR

105 new GFEs

100% more fabs needed



# SmartAuto: the new Queen of the Market

SmartPhones are no longer the growth driver

The Auto Industry is  
Reinventing itself Again with  
ADAS & Electrification

- EV ~ **7 X** ICE Chip Content
- EV ~ **10X** Growth Potential

Auto is the **NBT** displacing the  
out-of-breath Smartphone

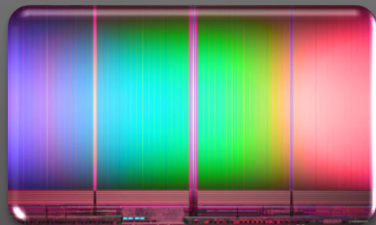


# Chip Innovation Engine *Relentlessly Drives Opportunity*



## Macroeconomic

COVID MMT National Security PowerGrid  
AI-everywhere AR/VR Zooming Lifestyle Data Security Climate  
Auto\SDV\ADAS Data Center *as a Profit Center* Data Economy Change  
IoT SSD iMC 5G Cloud 3D Printing\Etching China  
Computational Medicine Factory 4.0 Quantum Computing



## Semiconductors

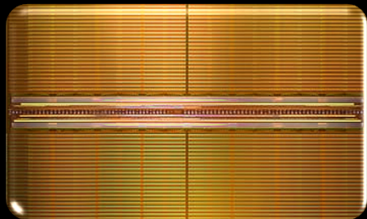
Law of PPACt Heterogeneous Integration  
GAA GaN CNT 2D Compound Semi NPUxPU Disaggregated Design  
Nanosheets DRAM 3DNAND 3DLogic CIS Trusted Fab  
Al-in-design DCTO PCRAM CrossPoint RF FPGA Chiplets  
RRAM



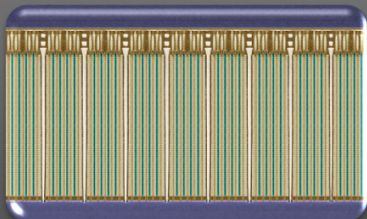
## Equipment & Materials

Multi-beam litho/inspection  
EUV revolution Optical DW EPE\LER Hi/LoK Curvilinear Masks  
Hi-NA-EUV Al-in-fab CNT 2D ALD DSA Dry Resist NGinterconnect  
hyper-NA-EUV HAR ALE Q-ALE Materials System Engineering Riblets  
Advanced Assembly Materials Enabled Scaling Selective-dep/etch

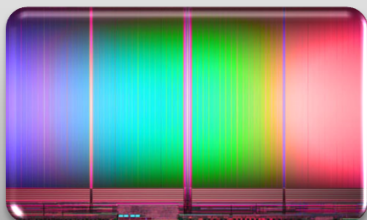
# Chip Innovation Engine *made possible by us...*



**DRAM**  $\text{DDR}_{N+1}$  ALD HAR Gap Fill Selective-dep/etch NGMs  
 3D DRAM  $\text{GAA}_{\text{enabled}}$  EPE\LER Co capping Hi-Mobility Channel TSV  
 Copper EUV revolution LoK Dielectric NGM-Hard Mask  
 Low R Metal DCTO Al-in-fab HKMG Advanced Doping  
 Advanced Interface Engineering



**NAND** V-Limit: H-Scaling Low-Dishing CMP 2D Nanosheets  
 ALE<sub>NG</sub> RRAM Hybrid W2W Bonding CMOS Over/Under Array  
 PCRAM Hole-Thinning 3DNAND Hi-Modulus ON Zig-Zag Staircase  
 CrossPoint DCTO NGM-Hard Mask HAR Gap Fill  
 Advanced Interface Engineering  
 Optimized Implant/Anneal

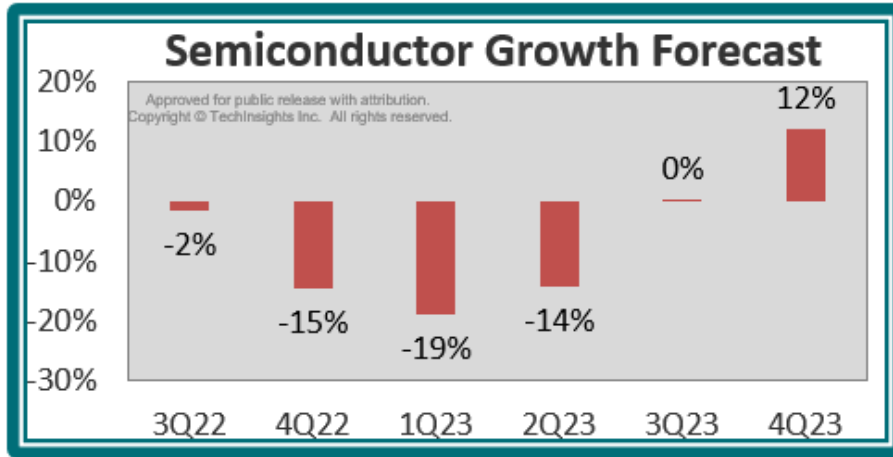


**LAP** *Logic, Analog & Power* GAA hyper-NA-EUV  $\text{GAA}_{\text{enabled}}$  eDRAM  
 EUV Hi-NA-EUV NGMs 3DLogic NGM-Hard Mask  
 Law of PPACT GaN TSV EPE\LER Hi/LoK  
 Al-in-fab Curvilinear Masks DCTO Q-ALE Dry Resist Chipleets CNT 2D  
 Heterogeneous Integration Compound Semi Selective-dep/etch  
 Materials Enabled Scaling Optical DW Advanced Interface Engineering

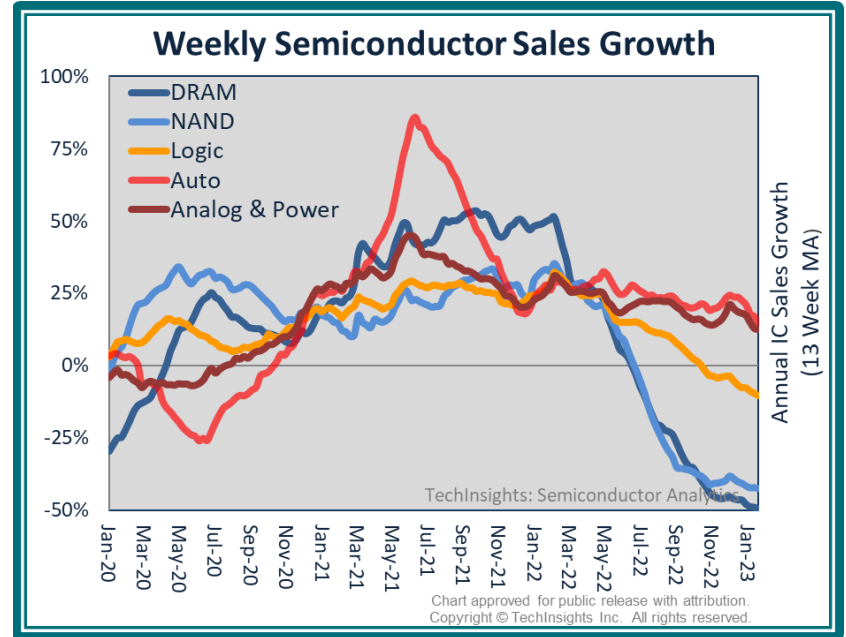


## Near-Term Semiconductor Outlook

**2023 Forecast: 581 \$B -6%**  
2022 618 \$B 5%



Updated: 21-Feb-23





# IC Sales Growth: Overheated or Underheated?

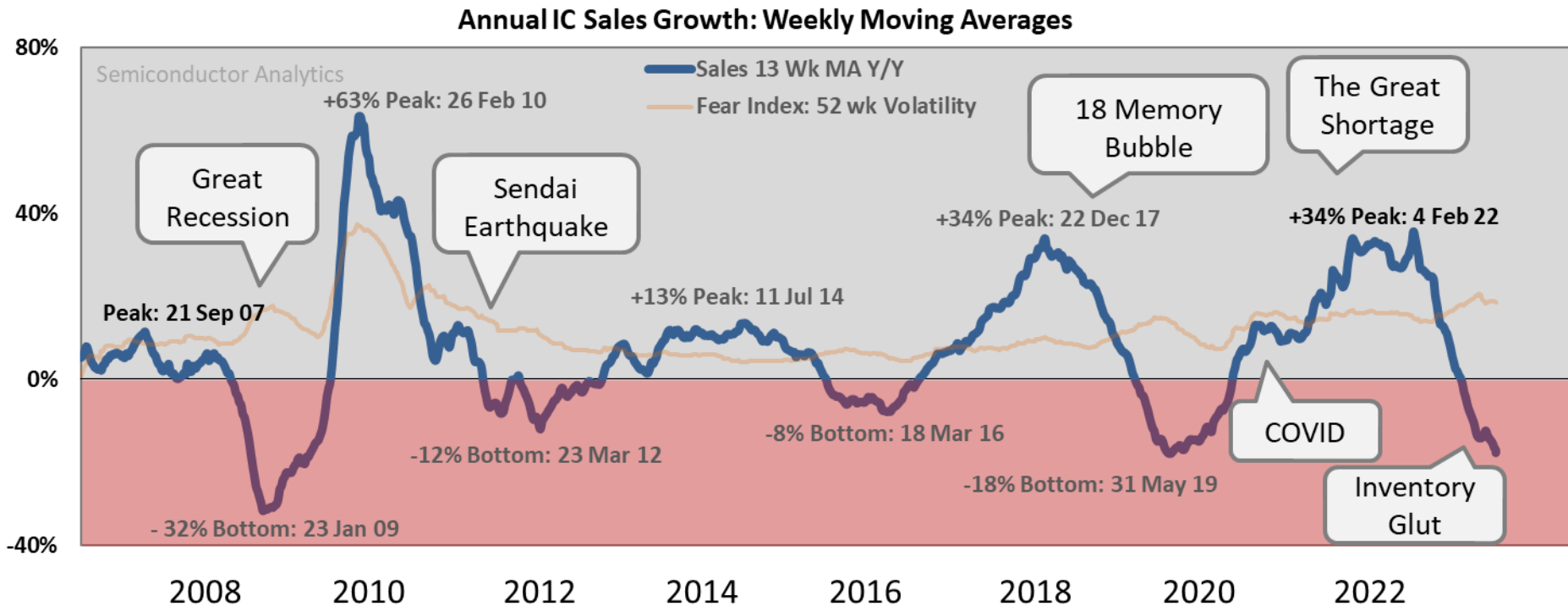


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# Trendlines to 2030

## Path to a Trillion Dollars

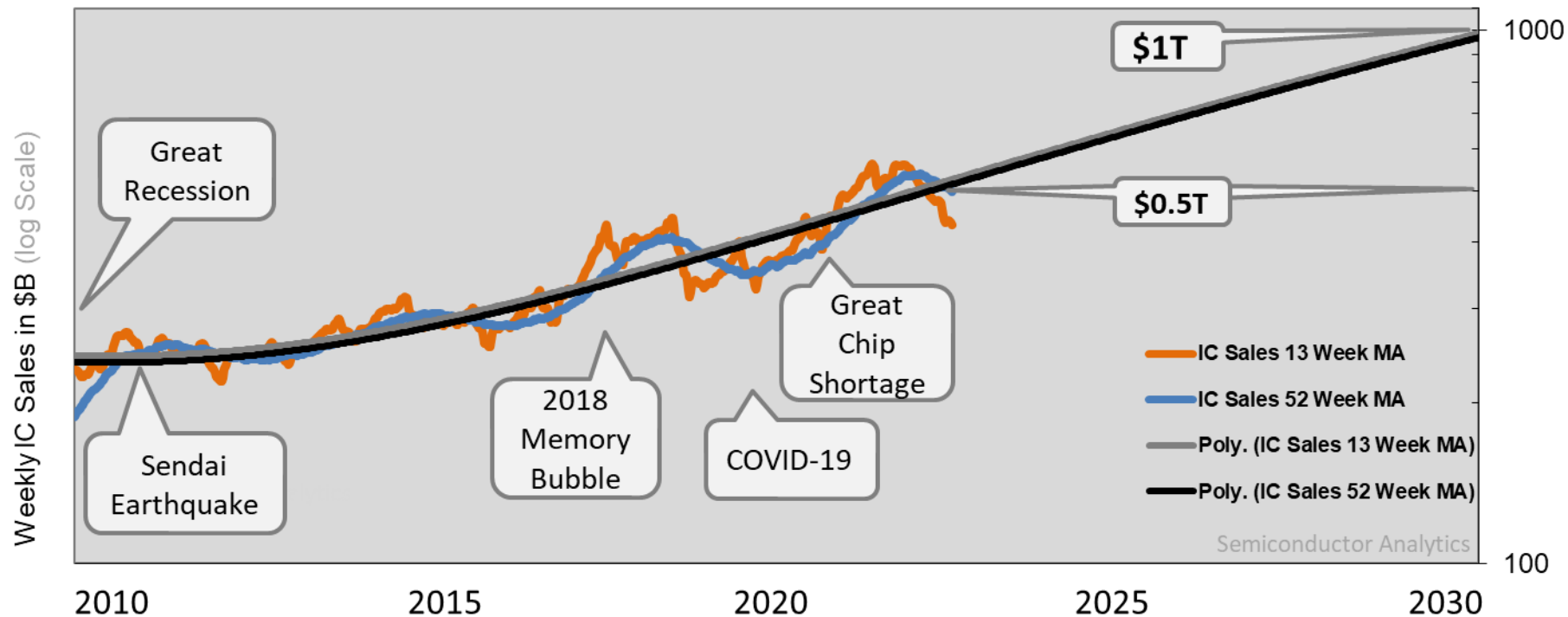


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# IC Supply/Demand Trends

## Last Week's Semiconductor Supply/Demand Heat Map

	4Q 2021	4Q 2022	10-Feb-23	17-Feb-23	
Overall	Tight	Tight	Tight	Tight	Glut
DRAM	Balanced	Saturated	Saturated	Saturated	Saturated
NAND	Tight	Balanced	Balanced	Balanced	Balanced
IDM	Tight	Balanced	Balanced	Loose	Loose
Foundry:	Balanced	Balanced	Tight	Tight	Balanced
More Moore	Balanced	Balanced	Tight	Tight	Tight
More than Moore	Balanced	Tight	Shortage	Shortage	Shortage
OSAT	Shortage	Balanced	Shortage	Tight	Shortage
Analog & Power	Tight	Tight	Tight	Balanced	Shortage
Auto IC	Shortage	Shortage	Shortage	Shortage	Range:

Semiconductor Analytics

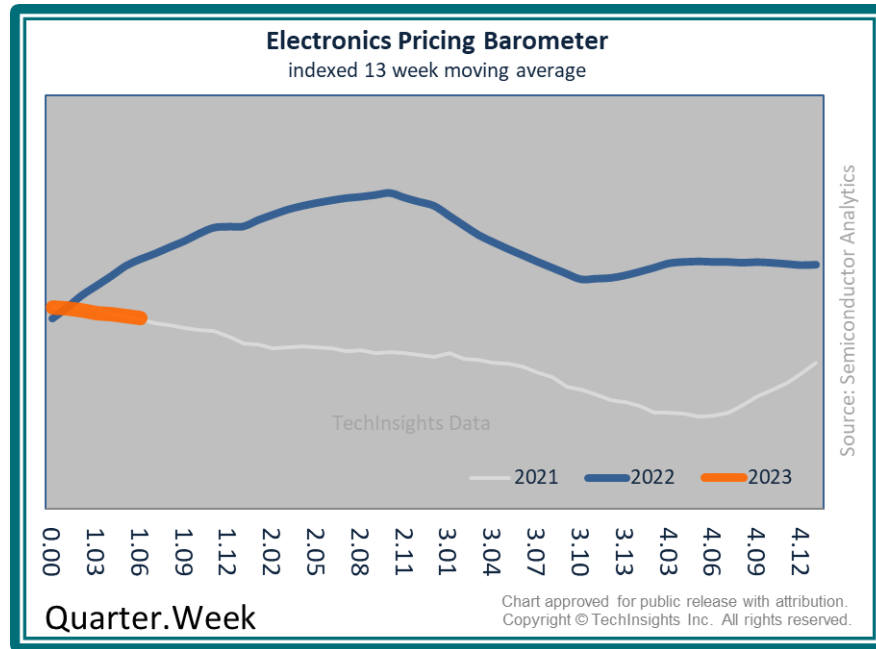
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TechInsights' IC Supply/Demand held in Tight conditions. IDM, OSAT, and Analog & Power all loosened this week. IDM went to Loose from Balanced, OSAT to Tight from Shortage, and Analog & Power moved from Tight to Balanced. The remaining segments stayed the same.

# Electronics Retail Pricing Trends

For PC Notebooks Tablets, Smartphones, Cell Phones, Digital Cameras, Appliances, TVs

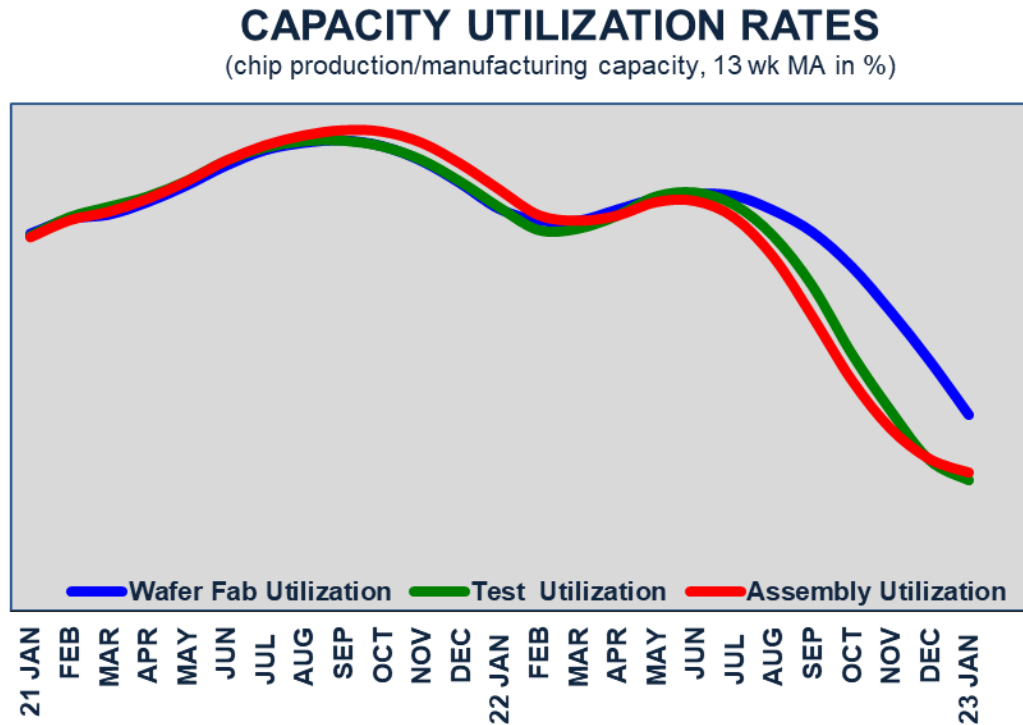
Electronics'  
Retail Prices  
are trending  
down





# What about Semiconductor Utilization?

- All sectors falling
  - Wafer Fab
  - Test
  - Packaging
- Off >10% peak levels

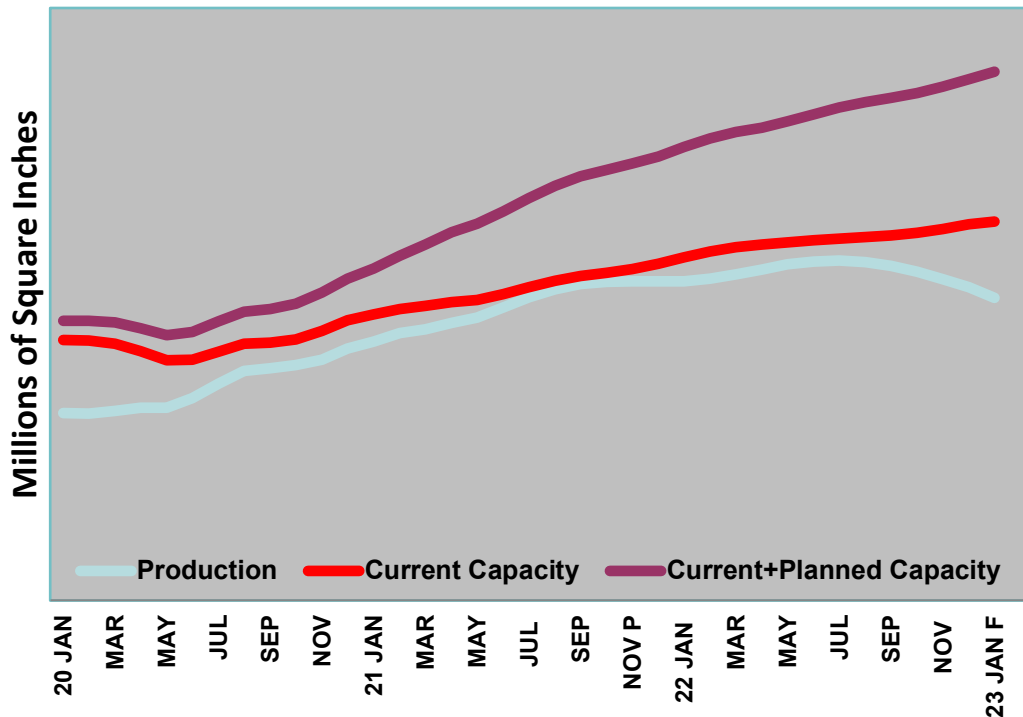


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# What about Planned Fab Capacity?

- Current plans add
  - ~25% of Current
  - 2.5x Average

Production and Capacity Plan



# What about Semiconductor Inventory?

- The Inventory-to-Billings Ratio is...
  - in an expansionary range
  - Above critical levels
- Customer complaints about extreme shortages were a sign of multiple bookings

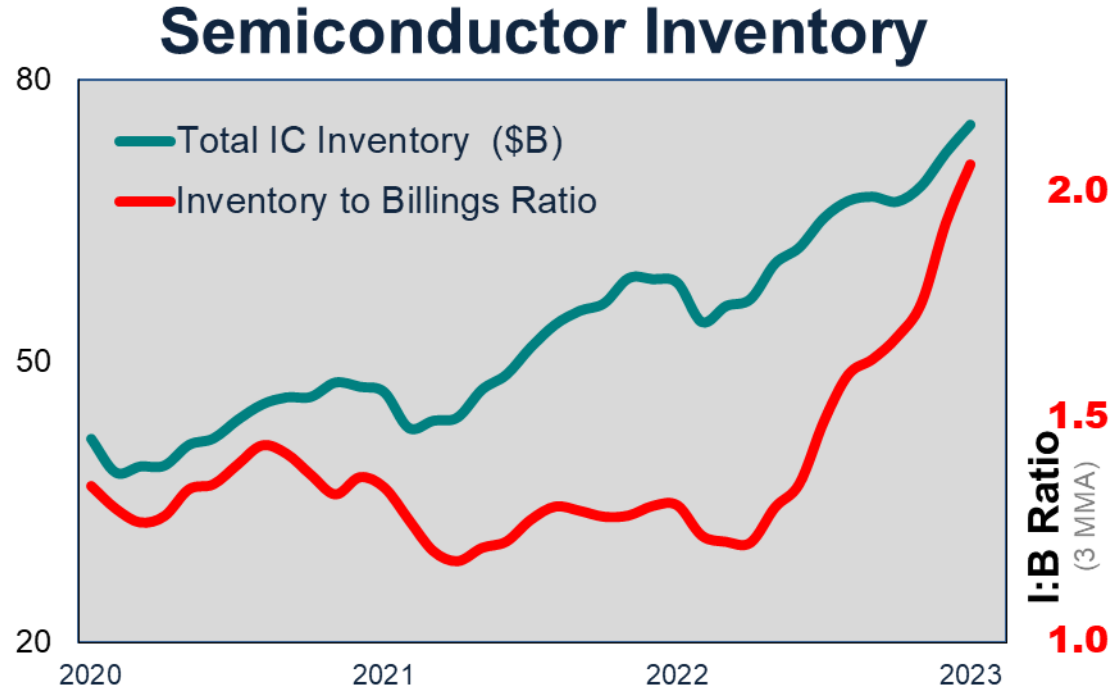


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# Concerns

## A Double Dip





# Concerns

# Inflation



# Concerns

# Hoarding





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