

2023 Memory Downturn and Recovery: Causes and Effects

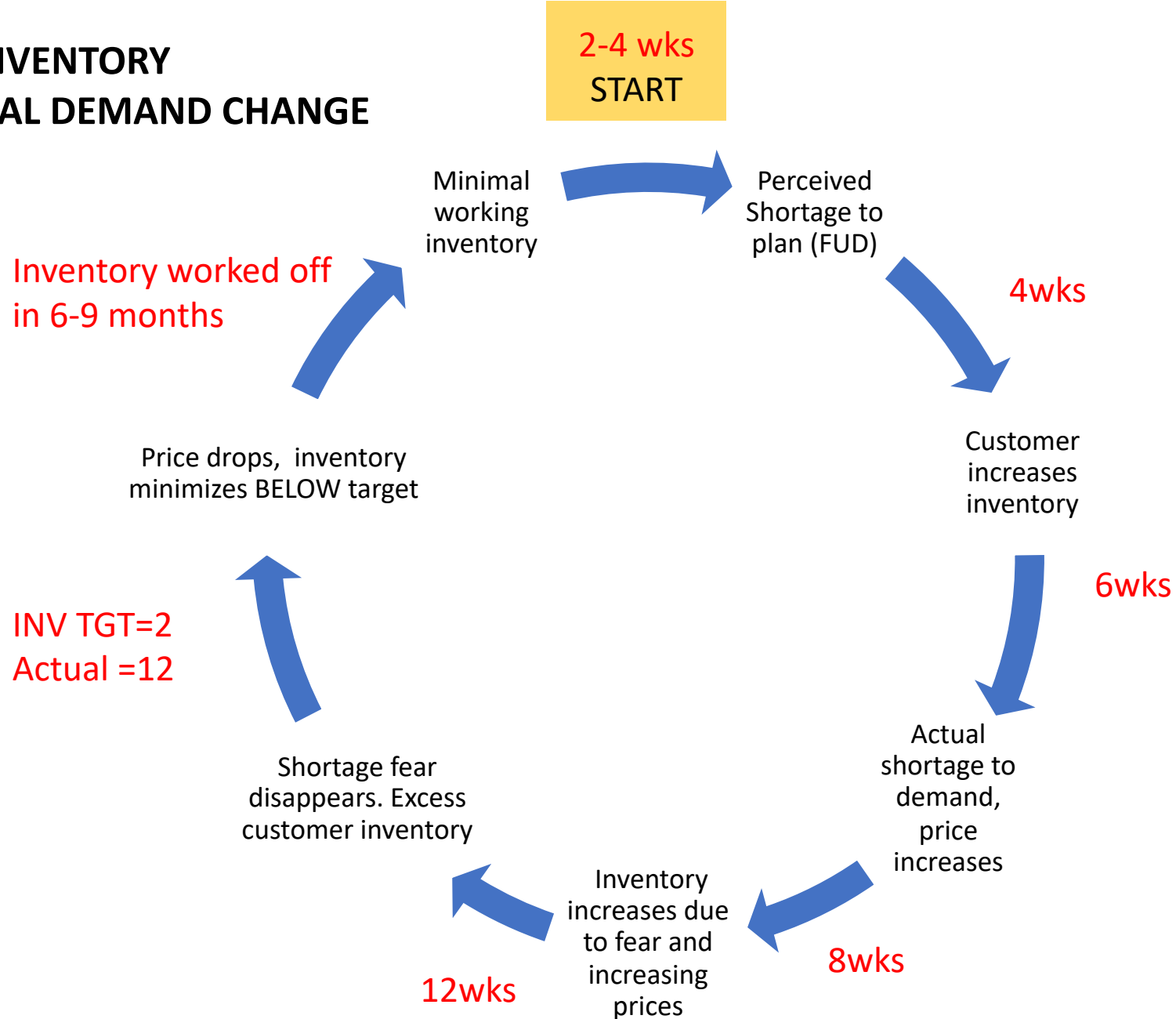
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- Memory Market Cycle
- Reasons and Typical Numbers
- 2022 Crash Actual vs. Predictions
- Conclusion of Crash
- Requirements for Successful Future

THE CYCLE OF INVENTORY

NOTE: NO ACTUAL DEMAND CHANGE



= Customer Inventory

The Cycle Always Repeats

- The cycle is predictable with human and business causes
 - Increase inventory for fear, buy more ahead of time if price is going up
 - Run below target inventory, buy less IF the price is going down
 - It takes 6-9 months to work off 10 weeks of excess inventory (up for negotiation)
- 2025 will see high prices and a shortage, 2026 will see a crash.
 - Not due to AI, invasions, pandemics, elections, interest rates, movies, culture wars ...
 - It's all positive feedback oscillation. An Excel macro can predict it.
- Long-term supply agreements and pricing agreements are NOT a fix
 - They help customers, NOT suppliers. See me for details !!
- NOTE: This is all INDEPENDENT of any ACTUAL change in demand

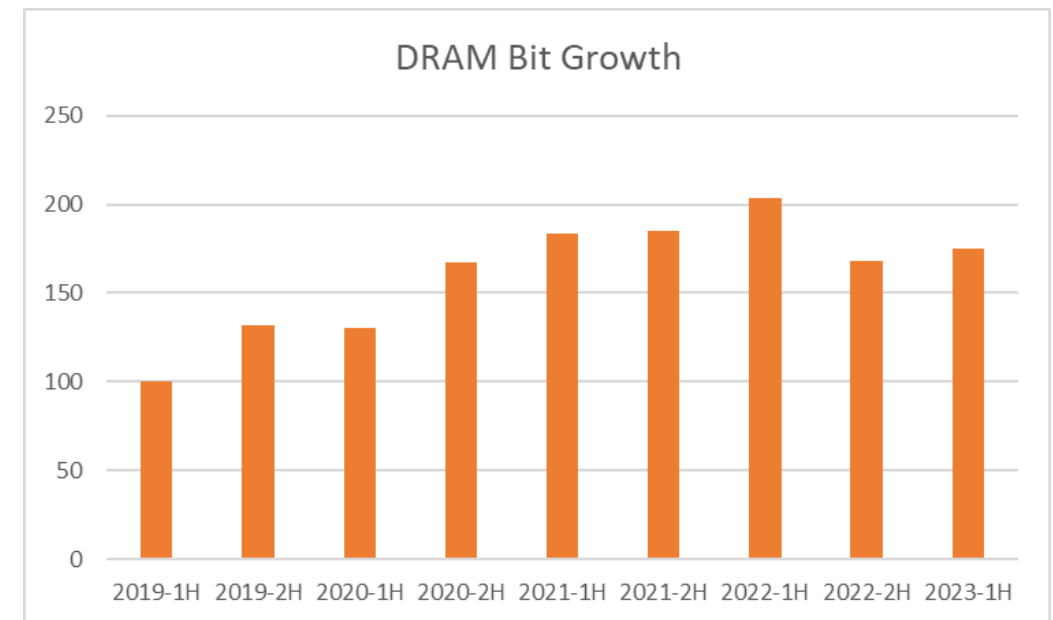
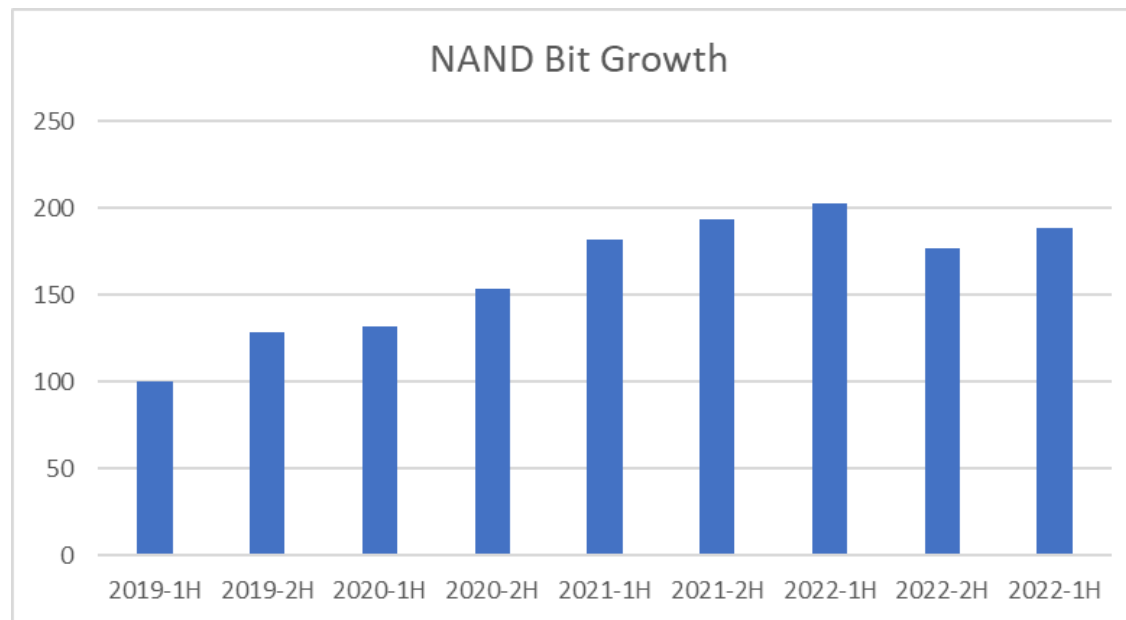
What was different this time?

- The cycle repeats like always, but we were not supposed to see devastation like pre-2010 time
- Oligopoly, restraint, modest growth were supposed to dampen this
- In July 2022, it started to drop like typical downturns.
- By end of Q3 2022, Suppliers started to cut starts (severe measures). They knew something was REALLY different this time.
- We all predicted a 6-9 month correction.... 6 months later, things are worse.
- Feb 2023, I met with multiple memory customers and got the answer -- and it explained everything !!
 - There was one problem with my numbers....

NAND and DRAM Bit Growth

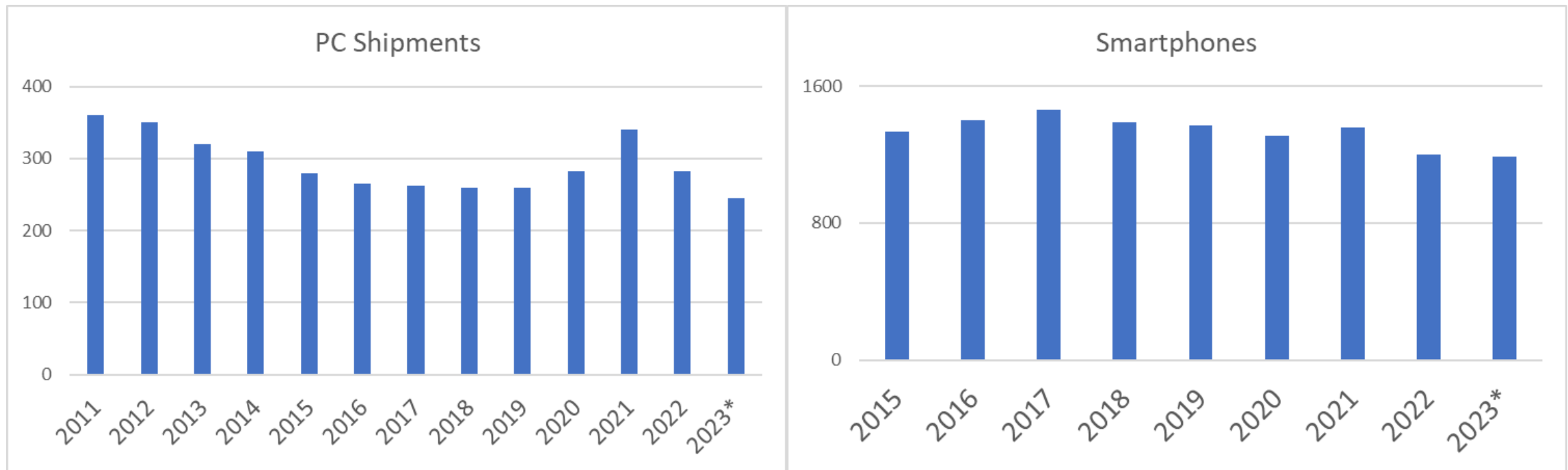
Both approximately 25% CAGR from 2019- Q2 2022

Note: Bits have never dropped YoY in the past



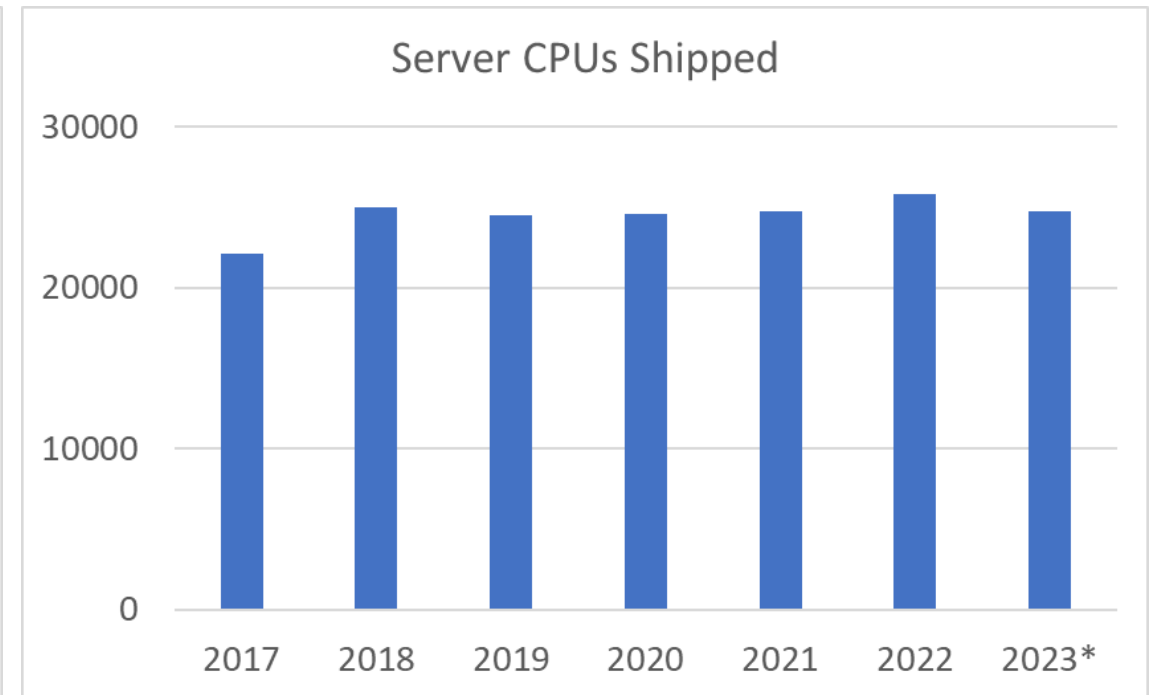
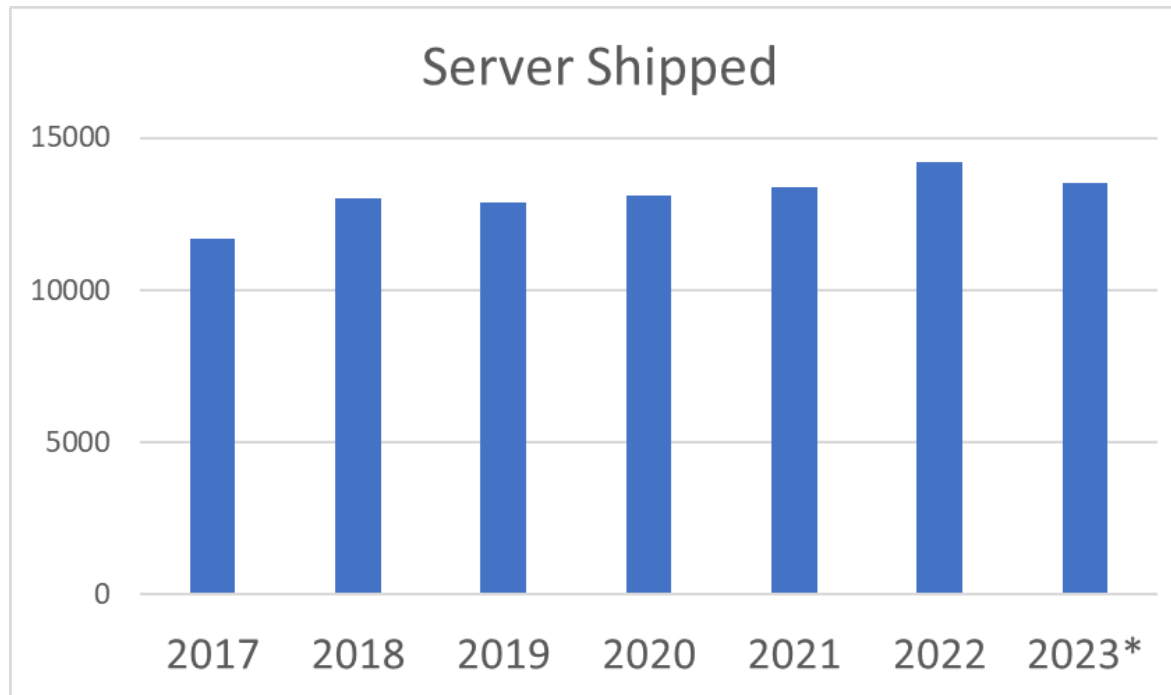
PC and Smartphone Sales

2021 was spike in purchases. 2022 doesn't look that far from trend



Server Units

Server units and CPUs growing steadily 5% CAGR



The Numbers

- Long-term DRAM bit growth is 15-18%. Even with AI/5G/edge/TikTok.... Actual was 25%
- Long-term NAND bit growth was predicted to be 25%, but it appears to be really 20%?
 - Especially if prices are not cratering.
- PC sales are declining, Smart phone sales have been declining for the last several years.
- Servers are on a steady 5% CAGR. Growth. We know about the digestion phase. 1H 2023 is bad..
- For all markets bits-per-unit is growing (Server highest)
- We know customers go into a cycle to deal with fear and pricing ... but why did suppliers ignore their own forecast and get trapped?
- Suppliers are saying that the 2021 pandemic boom was a “new baseline” -- and that growth would be from there. It is not clear that this is true . . .
- AI hype is nice but doesn't change the bit growth before 2024. AI was 1-2% of bits in 2022
- Summary: No clear end market crash. Looks like Q2/2020 to Q2/2022 boom was one time.
- Memory bit decrease in last 12 months was unprecedented. Nearline HDD shows same impact.

What About Supply Issues?

- Previous discussion assumed “everything normal” except inventory builds.
- NAND suffers from chronic oversupply challenges
 - “Arms race” to get to next layer faster than others, even when not needed. Why 2xx?
 - Commitment to 30% bit growth, but we are oversupplied 80% of time
 - Prediction was 25% growth... Same as actual. 20% or less might be new normal.
 - Lately Yields and output per tool improved much better than expected.
- DRAM added to this for the same “positive reasons”
 - Advancement in new nodes 1z,1a,1b showed better yields, better output per tool
 - Fab expansions announced that may not be needed.
- Demand and inventory is one thing, but if we choose to oversupply, hoping that growth catches up, it will be perpetually challenging.



Summary and Conclusion of Crash's Cause

- Memory sales went up above forecast in 2020-Q2 2022.
 - MOST of the reason was a continuous build of inventory that no one saw
 - Each reason stacked on top of previous reason. PLUS Fear of price increase
- DRAM Long-term demand is what we thought AND SAID it was in 2019. 15-18%
- NAND bit growth is probably 20% or less. Excessive price reduction increases it.
- Process arms race + yield and output execution caused extra supply.
- Q1 2022 showed PC and Smartphone weakness. That's OK, we have servers!
- Server digestion phase+ other items instantly eliminate supply fear.
 - 12+ weeks of EXCESS inventory instantly created
- PCs in digestion phase AND declining market; Phones flat to declining
- AI provided hype but was less than 5% of bit demand, so it doesn't help... yet
- Total bits sold from 2020-2023 will be EXACTLY what we expected in 2019 !!

The Recovery Scenario

- Market is cyclical and will recover.
 - We predicted Q3 start, Q4 ramp months ago and it is on track. Recover definition needed.
- The severity adds a few twists that we have not seen in over a decade
 - Prices can increase by 30% and STILL cause losses to memory companies.
 - Memory makers will not add or commit capacity at a loss (HOPEFULLY).
 - Burn inventory until customer fear of shortage and price increase cause change.
 - Prices to break even, Then talk about adding capacity back. Then decide how much.
- QUIZ: If prices are going up, should you buy ahead or wait? How much?
 - Mark's answer: ??????
- Things will get better in 2024, and 2025....
- Then guess what happens in 2026????
 - Hopefully, it will be less severe

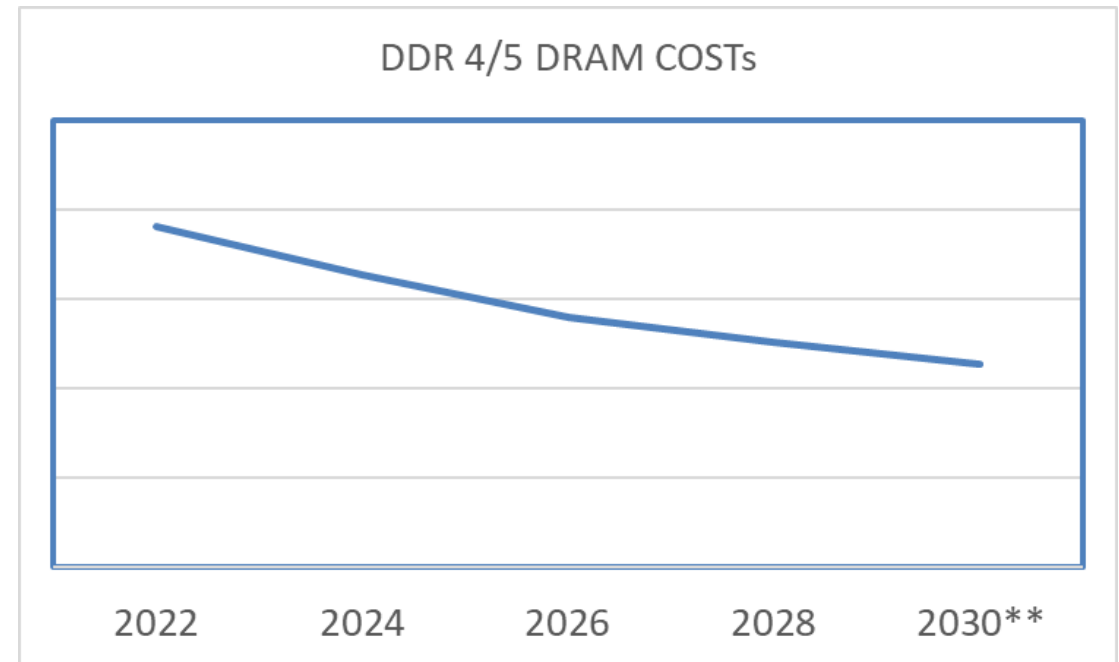
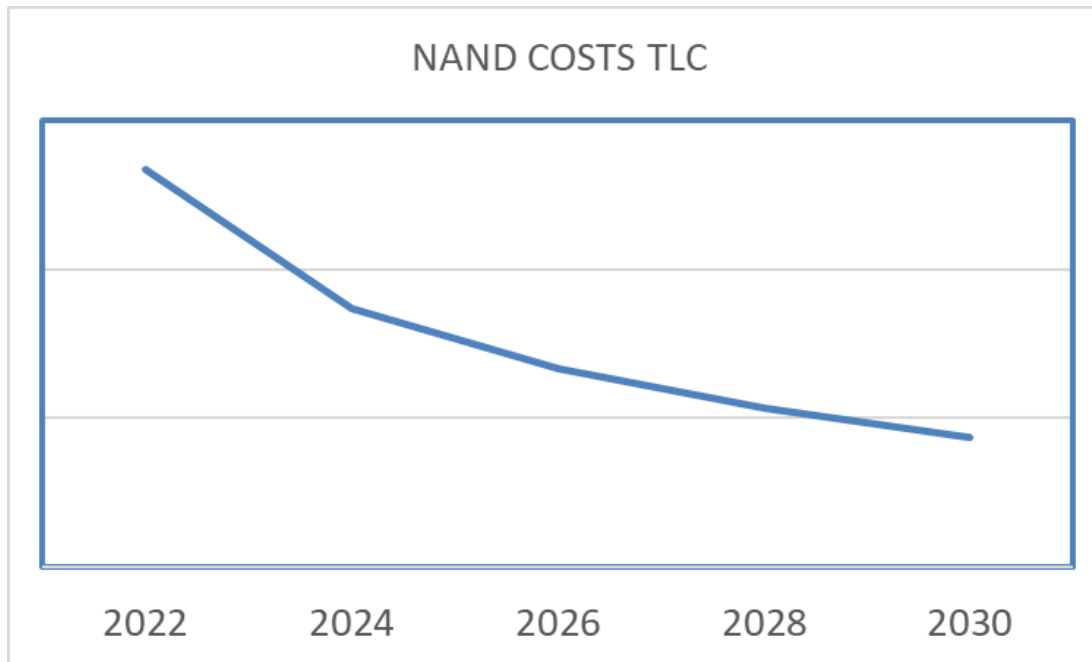
The Long Term Solution

If you want to have an investable memory market

- DRAM: I liked it better when we said it's a boring mature market with limited growth and no process scaling.
 - 15-18% bit growth. Ramp new technologies slowly to provide growth. Don't race to 1Gamma. Be rational, don't fall for inventory build trick
 - Cost reduction from new tech is minimal (at least until 3D). Don't rush.
- NAND: We still have 1-2 too many companies. All are in arms race.
 - Someone is ALWAYS willing to cut price and to excessively grow bits
 - Long-term margins are not good. Focus on margins and not on pushing bit growth
 - Slow arms race. One company tried and still got burned.
 - Stop pushing for higher bit-growth options. Do NOT try to replace HDD/nearline. Do the math to see what the AI impact to memory demand actually is.
 - Do not oversell Layers PLUS 5 bits per cell PLUS fab additions
 - Please tell me we are not going to build all these Fabs.

We Can Still Do Cost Reduction

IF there is ROI. NAND down 10-12% CAGR, DRAM down 5-10% CAGR
Greatly reduced from my 2022 prediction



Summary

- Memory crash was the result of long-term buildup of inventory in fear/anticipation of supply chain issues and rising prices.
 - Inventory size was MUCH higher than originally thought
- PC, Smartphone softness weakened market. Final straw to eliminate fear was the server digestion phase in 2H 2022.
- Excess inventory went from zero to 12+ weeks in all markets.
- End markets are on same trend as 2019, ignore 2020-2022. This is a reset.
- Recovery starts now, ramps depending on recovery definitions. Spikes when fear of shortage returns (GM need to quickly go to 30%)
- Long-term solution is to restrain supply as growth SEEMS to exceed forecast.
 - No arms race, No extra fabs, No supporting customer inventory builds, No excessive hype.
 - We have detailed tactics for both suppliers and for the customers of memory

Thank You!

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