SSDs will crush hard drives in the enterprise, bearing down the full weight of Wright's Law

By **Chris Mellor** - January 25, 2021

IDF Merkava Mk4 tank with Trophy APS ("מעיל רוח") during training

The supposed limitation of flash memory manufacturing capacity compared with hard disk drive manufacture is a "myth", according to the Wikibon Research analyst David Floyer.

More flash capacity is already made than HDD capacity. This volume production superiority is driving flash prices down faster than disk drive prices and, as night follows day, SSDs will take over from HDDs in data centres.

Using 'Wright's Law' as a reference point – more on that later – Floyer forecasts that production efficiencies will result in SSDs becoming cheaper than HDDs on a dollar per terabyte basis by 2026. The benefits will spill over to the enterprise uses cases that are currently dominated by nearline hard drives.

After 2025, Floyer writes, "Wikibon projects the HDD shipments will decline by about 27 per cent per year. The main reason is that flash will be the dominant technology for

almost all large-scale storage. HDD production will primarily be for the replacement and extension of existing HDD installations."

SSDs are cheaper to operate than disk drives, needing less power and cooling, and are much faster to access. But they cost more to make. Floyer's prediction of mass disk drive replacement hinges on the idea that SSDs will become cheaper on a $/TB basis, because of Wright's Law, and so become cheaper than disk drives. But when?

Crossover timing

Wells Fargo senior analyst Aaron Rakers in August 2019 predicted enterprise storage buyers will start to prefer SSDs when prices fall to five times or less that of hard disk drives. He noted an 18x premium in 2017 for enterprise SSDs over mass capacity nearline disk drives. This dropped to a 9x premium in 2019. He did not predict when the 5x premium crossover point would be reached.

Intel thinks it will happen in just under two years time. SSDs will reach total cost of ownership crossover with hard disk drives in 2022. This is because penta level (5bits/cell) 3D NAND will lower SSD cost. Rob Crook, Intel's general manger of its Non-volatile Storage Group, said at an Intel event in in December last year: "We're on the right path to replace HDDs," and Intel has solid plans to move to PLC in the future.

Floyer disagrees with this timing, citing Wright's Law in evidence.

The Wright Stuff

Wikibon argues the cross-over timing between SSDs and HDDs can be determined using Wright's Law. This axiom derives its name from the author of a seminal 1936 paper, entitled 'Factors Affecting the Costs of Airplanes, in which Theodore Wright, an American aeronautical engineer, noted that airplane production costs decreased at a constant 10 to 15 per cent rate for every doubling of production numbers. His insight is also called the Experience Curve because manufacturing shops learn through experience and become more efficient.

In a new Wikibon report, QLC Flash HAMRs HDD, Floyer has applied Wright's Law to NAND and HDD production. Wright's Law predicts cost-saving efficiencies will be made in line with increased production of NAND flash products. This means total production of NAND, adding together consumer and enterprise SSD products. The production of consumer and enterprise SSDs together builds product volumes high enough for Wright's Law to have its beneficial effects on pricing, according to Floyer's analysis.

Conversely, the scope for production-related efficiencies for HDDs falls as fewer disk drives are made. The outcome is that SSD $/TB will drop faster than HDD $/TB.

"Wikibon projects that flash consumer SSDs become cheaper than HDDs on a dollar per terabyte basis by 2026, in only about 5 years (2021)," he writes. "Innovative storage and processor architectures will accelerate the migration from HDD to NAND flash and tape using consumer-grade flash. …

"Flash is lower cost over 5 and 10 years for almost all file-based workloads than HDD, when storage management and space are factored in." Also, he notes, "Flash has already overtaken HDDs in total storage petabytes shipped."

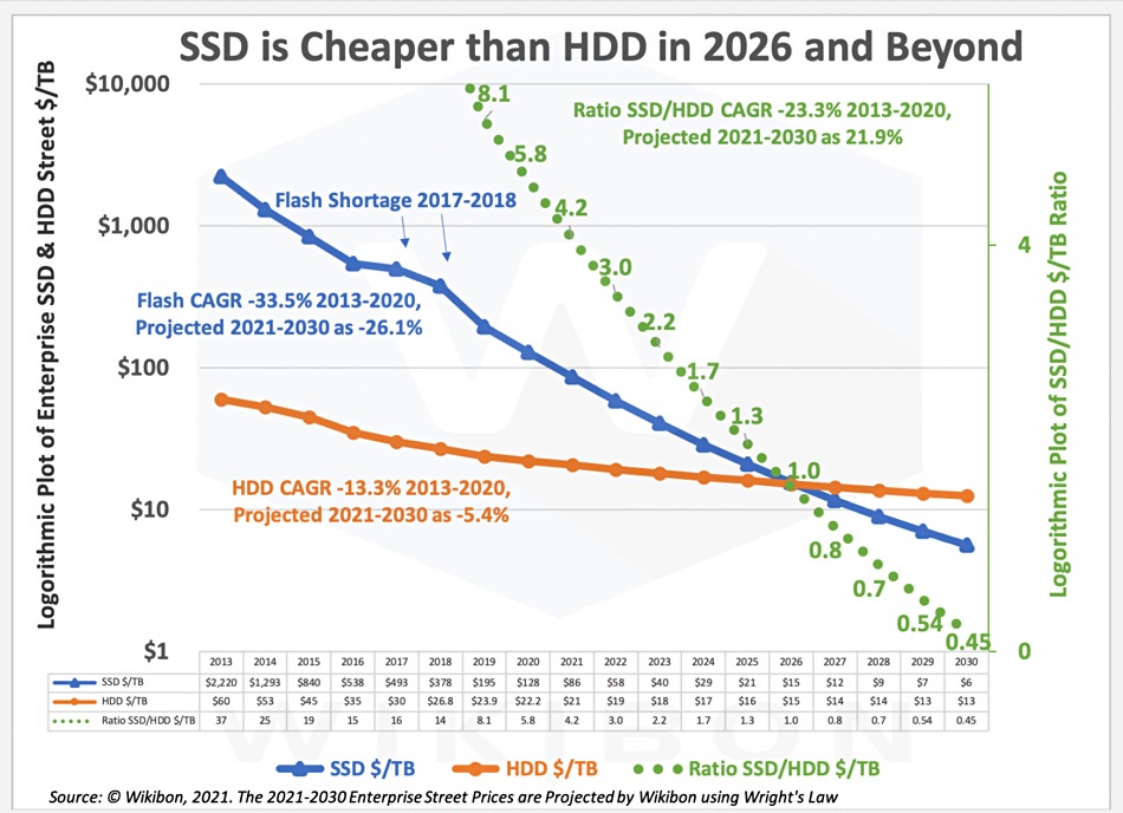
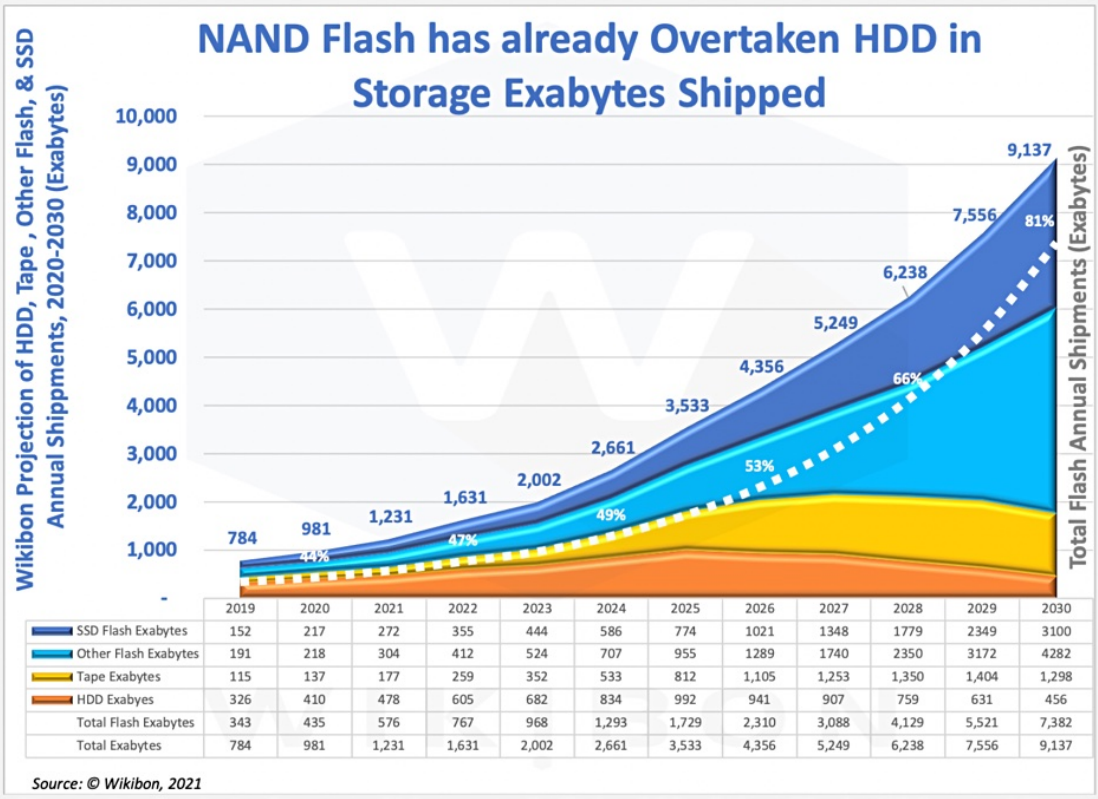


Figure 4 - SSD/HDD Pricing Ratio 2013 - 2030

Source: © Wikibon, 2021.

In the chart above, the orange line in this log-scale x-axis chart is the hard disk drive (HDD) $/TB street cost over time, plotted against the left-hand x-axis. The blue line represents the street $/TB SSD cost over the same time period, and the two lines are projected to cross in 2026. The green dotted line stands for the ratio between the SSD and HDD costs, plotted against the values on the right vertical axis.

Wikibon's Floyer includes a chart entitled "NAND Flash has already Overtaken HDD in Storage Exabytes Shipped." This shows that more flash exabytes are already being manufactured than disk exabytes.



	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
SSD Flash Exabytes	152	217	272	355	444	586	774	1021	1348	1779	2349	3100
Other Flash Exabytes	191	218	304	412	524	707	955	1289	1740	2350	3172	4282
Tape Exabytes	115	137	177	259	352	533	812	1,105	1,253	1,350	1,404	1,298
HDD Exabyes	326	410	478	605	682	834	992	941	907	759	631	456
Total Flash Exabytes	343	435	576	767	968	1,293	1,729	2,310	3,088	4,129	5,521	7,382
Total Exabytes	784	981	1,231	1,631	2,002	2,661	3,533	4,356	5,249	6,238	7,556	9,137

Figure 9 - Exabyte Storage Shipments Split by SSD, Other Flash, HDDs, and Tape
Source: © Wikibon, 2021.

The dotted white line on the chart shows annual flash shipments in exabytes, representing the sum total of SSD capacity and consumer flash products such as USB sticks and camera cards. The orange area represents total HDD exabyte shipments over time.

According to Floyer, the table at the bottom of the chart "shows that total flash accounted for 435 exabytes in 2020, compared to HDD with 310 exabytes. Most of the 'other flash' segment is consumer flash, and the fabs are already built and in production. More will be steadily built over the next decade. The cost of flash includes the investment in flash fabs. Myth exploded."

To this end, "Wikibon believes that the HDD industry will continue to develop PMR technology and should get to between 24-26 TB/HDD drive in the next five years."

Floyer writes: "The volume of consumer HDDs shipped was rapid in the early days. This volume drove down the HDD cost (Wright's Law), which drove increased HDD volumes to be purchased. The rapid increase in sales allowed for aggressive research and development to implement new HDD storage technologies with improved storage density.

"Initially, these new technologies were more expensive than the previous ones. However, the high volumes drove production costs down quickly (Wright's Law), and costs continued to decline."

Flash manufacturing limitation?

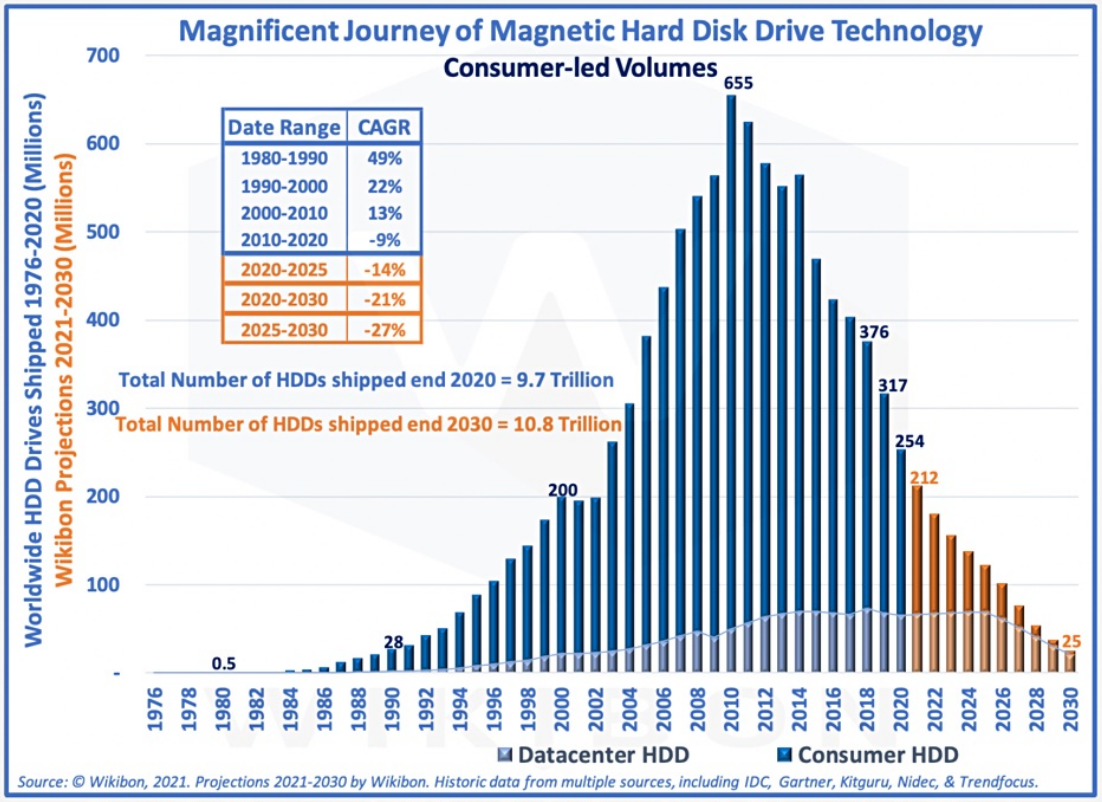


Figure 7 - History and Wikibon Projection of HDD Shipments (millions)

Source: © Wikibon 2021

Floyer chart showing actual HDD unit numbers to 2020 and projections to 2030. Consumer and enterprise (data centre) HDDs are separately indicated. He says consumer HDD unit numbers drove the production efficiency cost-savings

Members of the HDD preservation society say HDDs will retain their current $/TB advantage by increasing capacity through HAMR and MAMR technology. These heat and microwave energy-assisted magnetic recording technologies enable a disk platter to have much smaller bits and more tracks on the platter surfaces. That drives up areal density and so lowers the cost/TB.

According to this viewpoint, SDDs will retain their 5x or greater cost premium despite lowering their own cost/TB because HDD capacity is getting less expensive at the same or a greater rate.

HDD preservation society members also say that there is simply isn't enough flash manufacturing capacity to match the millions of petabytes of disk drive manufacturing capacity that exists today.

For example, Colm Lysaght, a senior director at Micron, the US memory maker, took this tack, telling *Blocks & Files* by email in August 2019: "Clearly SSD price/GB will get closer to HDD price/GB over time. … However, the raw number of EB needed for a "wholesale switch" from nearline HDD to SSD is far too large for the NAND flash

industry to contemplate. The capital investment needed to generate the EB required … is prohibitively expensive."

He concluded: "SSDs may nibble (and maybe even munch) at the nearline HDD market, but both will coexist for many years to come."

HAMR and MAMR dead end

Floyer thinks disk technologies like HAMR and MAMR will not change the outcome as it will not be financially viable for the HDD manufacturers to introduce them in mass quantities. This is because the number of drives required to reduce HAMR/MAMR costs below current HDD recording technology costs is too great.

Floyer writes: "Wikibon believes HDD vendors of HAMR and MAMR are unlikely to drive down the costs below those of the current PMR HDD technology."

He concludes: "In Wikibon's opinion, investments in HAMR and MAMR are not the HDD vendors' main focus. Executives are placing significant emphasis on production efficiency, lower sales and distribution costs, and are extracting good profits in a declining market. Wikibon would expect further consolidation of vendors and production facilities as part of this focus on cost reduction."