TMRC 2022 conference Technology Survey
Aug 2022, Western Digital Milpitas Campus., CA

Survey this year 1/2

Survey of opinions on technology intercepts for HDD and MRAM industry.

*** 1. Describe your affiliation ?**

- ◯ HDD Industry Member
- ◯ MRAM Industry Member
- ◯ Academia
- ◯ Vendor
- ◯ Other

Survey issued continuously over the meeting period. Differs from pre/post survey past years.

•The response rate was lower this year, so we consolidated the pre and post conference survey into one.

*** 2. What is the Maximum Areal Density Capability expected for Perpendicular/Shingled/Two dimensional - magnetic recording extensions?**

3. What is the expected Year of Technology introduction to HDD Products ?

	2022	2023	2024	2025	2026	2027	2028	2030	Never
BPM	◯	◯	◯	◯	◯	◯	◯	◯	◯
HAMR	◯	◯	◯	◯	◯	◯	◯	◯	◯
MAMR	◯	◯	◯	◯	◯	◯	◯	◯	◯
HDMR(BPM+HAMR)	◯	◯	◯	◯	◯	◯	◯	◯	◯

Survey this year 2/2

MRAM questions…
. And second year for storage tech question

4. What is the expected STAND_ALONE MRAM capacity (Mega/Gigabits) per chip in 2023?

256 Mb	512Mb	1 Gb	2 Gb	4 Gb	8 Gb	N/A
○	○	○	○	○	○	○

5. What is the expected EMBEDDED MRAM capacity (Mega/Gigabits) per chip in 2023?

256 Mb	512Mb	1 Gb	2 Gb	4 Gb	N/A
○	○	○	○	○	○

6. What is the expected NAND capacity (Terabits) per chip in 2023?

1 Tb	2 Tb	3 Tb	5 Tb	10 Tb	N/A
○	○	○	○	○	○

Other (please specify)

7. Which 3 new Emerging Memory Technologies are expected to be delivered in the next 5 Years

- ○ NRAM, FeFET, FeCAP
- ○ ARAM, xxRAM, NAND.
- ○ NRAM, NAND, STXRAM
- ○ DWM, FeFET, Yoda

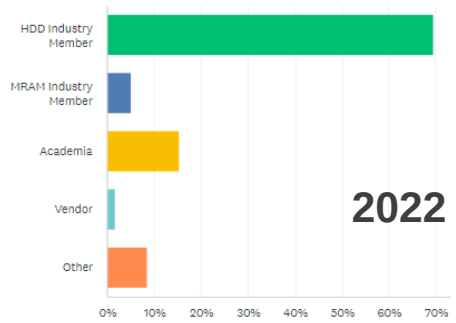
Second year for Q

Population of respondents up to 09/06/22 (post conference)

As with 2015-21.
Dominant responses from HDD members.
MRAM industry to still to break 10%

Describe your affiliation ?

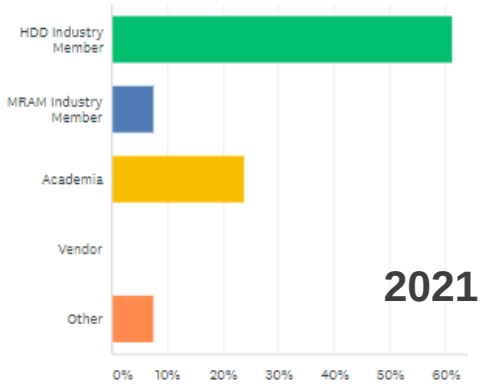
Answered: 59 Skipped: 0



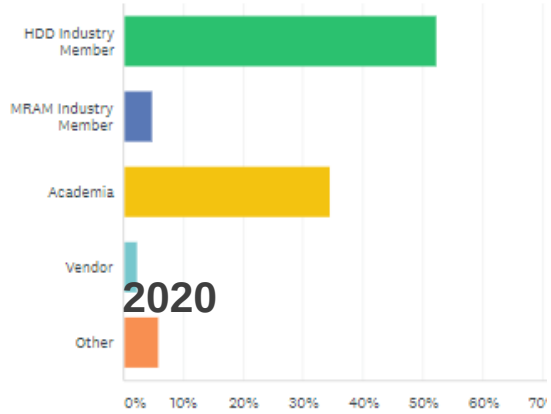
ANSWER CHOICES	RESPONSES	
HDD Industry Member	69.49%	41
MRAM Industry Member	5.08%	3
Academia	15.25%	9
Vendor	1.69%	1
Other	8.47%	5
TOTAL		59

Describe your affiliation ?

Answered: 67 Skipped: 0

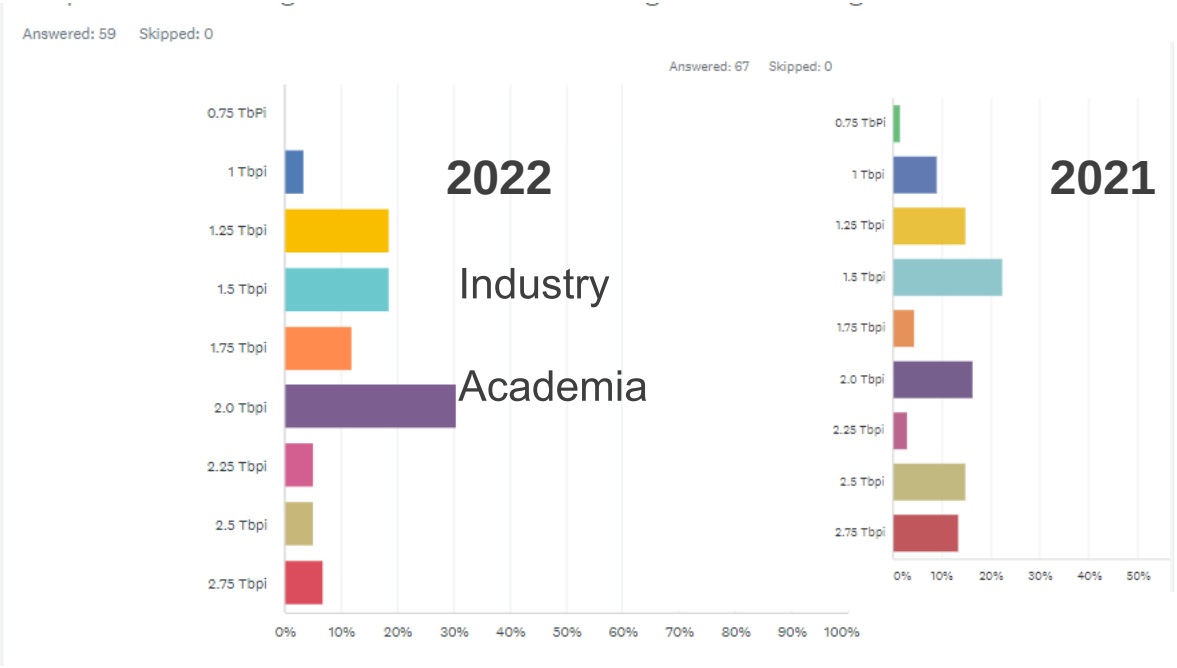


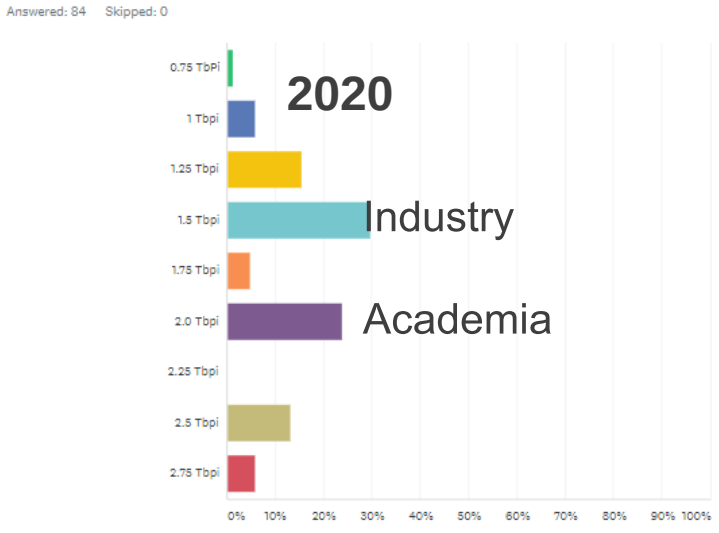
Answered: 84 Skipped: 0



Maximum ADC, for conventional technology

- **Median of 2 Tb/inch^2 +/-0.25, mean of 1.75 Tb/inch^2**
- **A few optimistic voters for 2.5 Tb/inch^2, and above.**
- **Bimodality between Academia and Industry (lower mode for industry)– which has increased in optimism this year.**
- **Pattern very similar to 2021/2020/2019/2018**





Expected introduction year

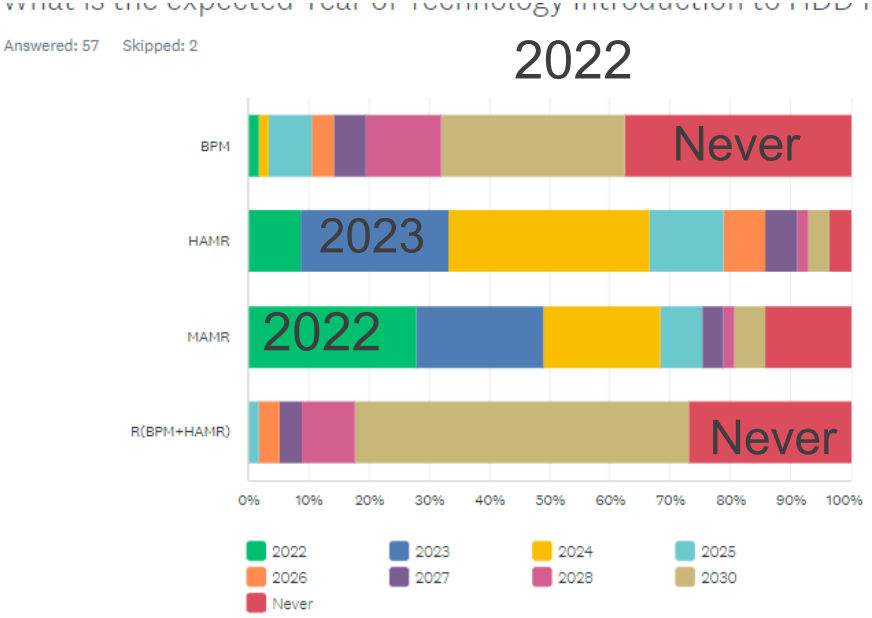
Pessimism for MAMR reduced in 2017, and improved 2018- drift back up 2019+ stayed.

BPM/Heated Dot remains pessimistic

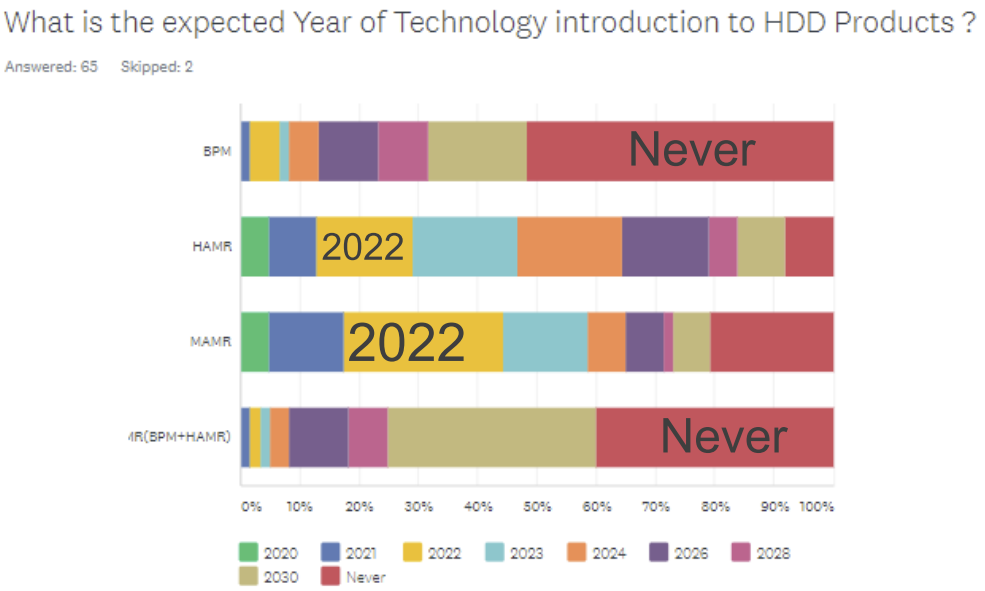
The last 3 years- MAMR and HAMR – is “soon”.

Focus in next slide on specific fraction of people that think a technology will not work

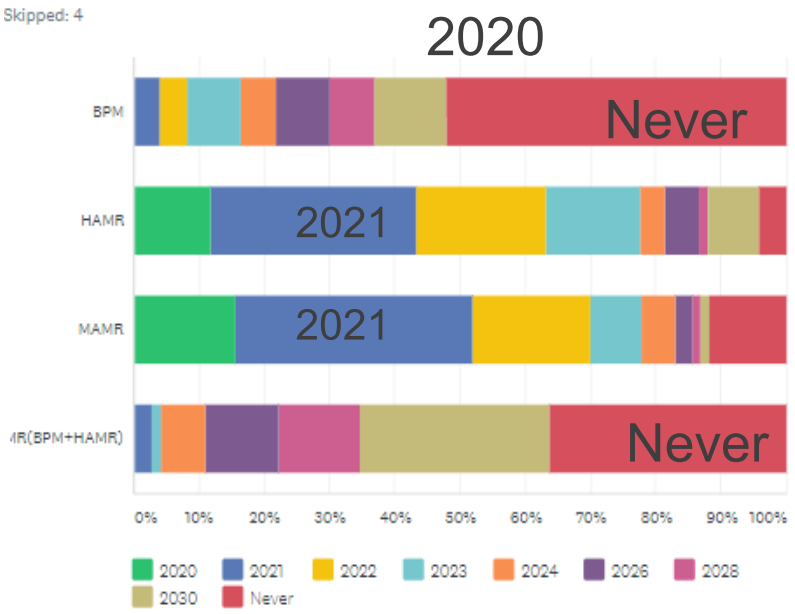
2022



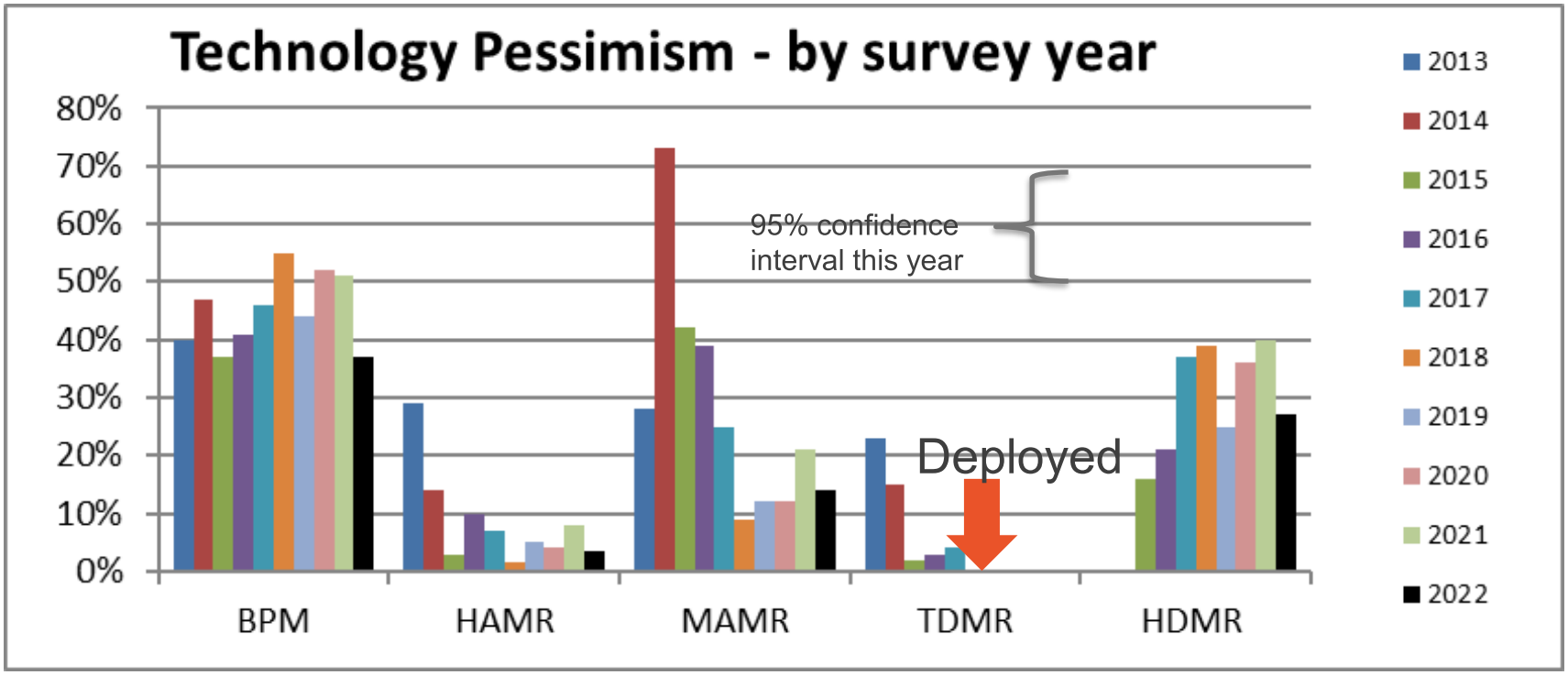
2021



2020



Technology pessimism(Never): Compare 2022 with 2021-2013



From left to right..

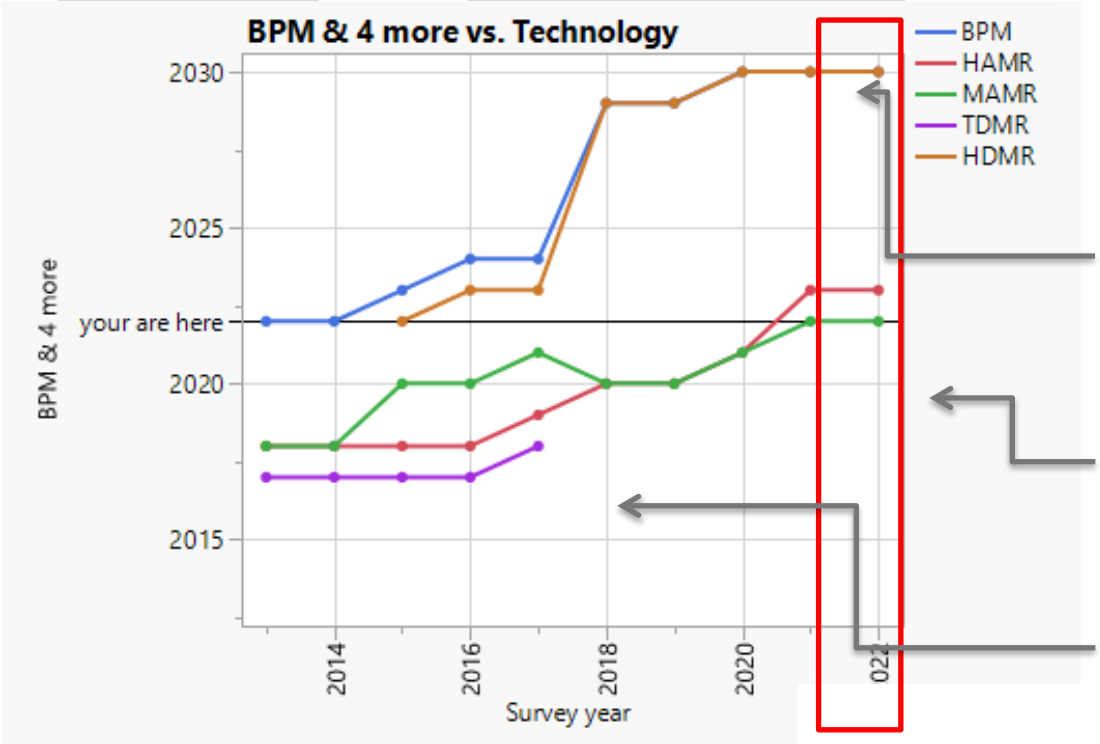
- **BPM appears stable and poor.**
- **HAMR confidence stable**
- **MAMR hit a bad patch 2014, started recovery in 2016-2017, and significantly improved 2018- improvement this year**
- **TDMR Launched 2017 into product – so removed 2018.**
- **HDMR confidence – better than BPM but still poor.**

Technology	BPM	HAMR	MAMR	TDMR	HDMR
2013	40%	29%	28%	23%	
2014	47%	14%	73%	15%	
2015	37%	**3%**	42%	**2%**	16%
2016	41%	**10%**	39%	3%	21%
2017	46%	7%	**25%**	4%	**37%**
2018	55%	2%	**9%**		**39%**
2019	**44%**	5%	**12%**		**25%**
2020	**52%**	4%	**12%**		**36%**
2021	**51%**	8%	**21%**		**40%**
2022	**37%**	4%	14%		**27%**

Technology Introduction year

Technology	BPM	HAMR	MAMR	TDMR	HDMR
2013	2022	2018	2018	2017	N/A
2014	2022	2018	2018	2017	N/A
2015	2023*	2018	2020*	2017	2022
2016	2024*	2018	2020*	2017	2023
2017	2024*	2019	2021*	2018	2023*
2018	2029*	2020	2020	-	2029*
2019	2029*	2020	2020	-	2029*
2020	2030*	2021	2021	-	2030*
2021	2030*	2023	2022	-	2030*
2022	2030*	2024	2022		2030*

*Pessimism is high
So confidence on introduction year is poor.

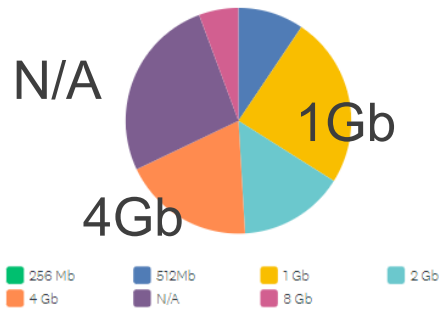


- BPM and HDMR continues to drift out.
- MAMR holds to this year, and HAMR pushed out “just one more year”.
- TDMR Launched 2017

MRAM questions- Stand Alone Memory

Answered: 53 Skipped: 7

2022



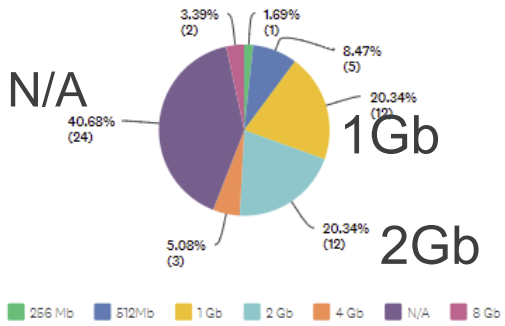
	256 MB	512MB	1 GB	2 GB	4 GB	N/A	8 GB	TOTAL	WEIGHTED AVERAGE
(no label)	0.00% 0	9.43% 5	24.53% 13	15.09% 8	18.87% 10	26.42% 14	5.66% 3	53	4.82

1 or ~~2~~-> 4 GB per chip remains most popular choice, and stable.

What is the expected STAND_ALONE MRAM capacity (Mega/Gigabits) per chip in 2022?

Answered: 59 Skipped: 8

2021

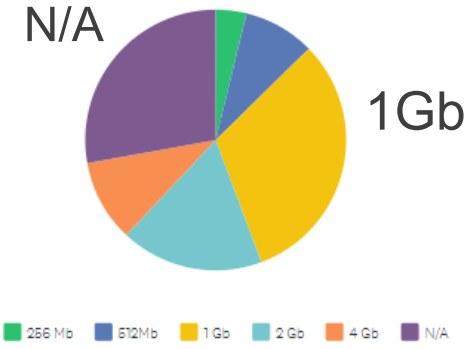


	256 MB (1)	512MB (2)	1 GB (3)	2 GB (4)	4 GB (5)	N/A	8 GB (7)	TOTAL	WEIGHTED AVERAGE
(no label)	1.69% 1	8.47% 5	20.34% 12	20.34% 12	5.08% 3	40.68% 24	3.39% 2	59	4.49

ıe expected STAND_ALONE MRAM capacity (Megabits) per chip in

ipped: 5

2020



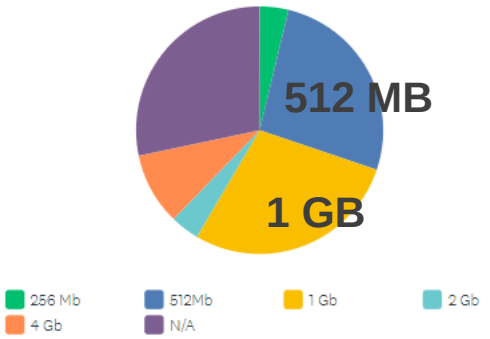
	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
	3.80% 3	8.86% 7	31.65% 25	17.72% 14	10.13% 8	27.85% 22	79	4.30

Embedded MRAM

Similar to 2018-2020
512 and 1 GB most popular
Moving more into 1GB node.

Answered: 53 Skipped: 7

2022

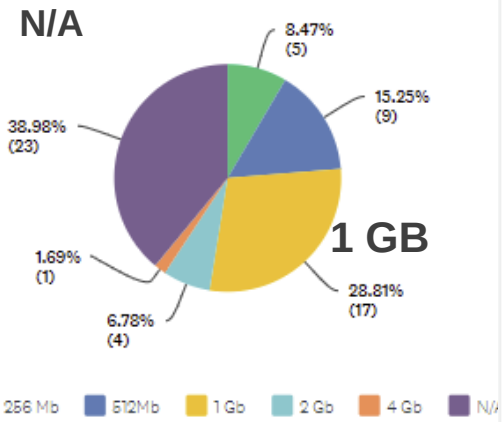


	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	3.77% 2	26.42% 14	28.30% 15	3.77% 2	9.43% 5	28.30% 15	53	3.74

What is the expected EMBEDDED MRAM capacity (Mega/Gigabits) per chip in 2022?

Answered: 59 Skipped: 8

2021

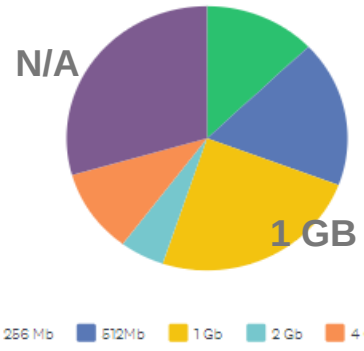


	256 MB (1)	512MB (2)	1 GB (3)	2 GB (4)	4 GB (5)
(no label)	8.47% 5	15.25% 9	28.81% 17	6.78% 4	1.69% 1

What is the expected EMBEDDED MRAM capacity (Megabits) per chip in 2021

Answered: 78 Skipped: 6

2020



	256 MB	512MB	1 GB	2 GB	4 GB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	12.82% 10	17.95% 14	24.36% 19	5.13% 4	10.26% 8	29.49% 23	78	3.71

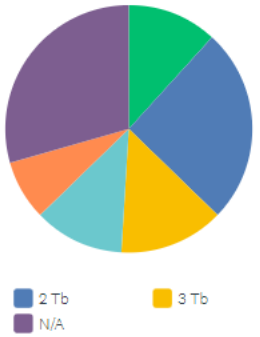
23 59 3.95

NAND Question

What is the expected NAND capacity (Terabits) per chip in 2023?

Answered: 51 Skipped: 9

2022



previous 2TB main choice(2020-21), now 3/5 TB getting similar votes

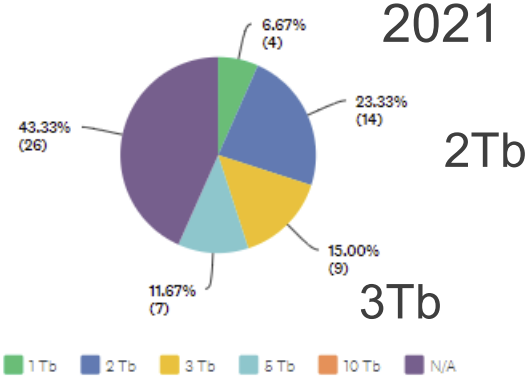
	1 TB	2 TB	3 TB	5 TB	10 TB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	11.76% 6	25.49% 13	13.73% 7	11.76% 6	7.84% 4	29.41% 15	51	2.69

Comments (0)

What is the expected NAND capacity (Terabits) per chip in 202

Answered: 60 Skipped: 7

2021

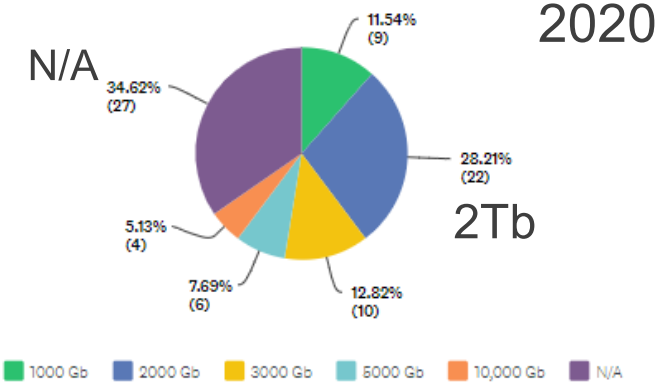


	1 TB (1)	2 TB (2)	3 TB (3)	5 TB (4)	10 TB (5)	N/A	TO
(no label)	6.67% 4	23.33% 14	15.00% 9	11.67% 7	0.00% 0	43.33% 26	

What is the expected NAND capacity (Gigabits) per chip in 2021?

Answered: 78 Skipped: 6

2020



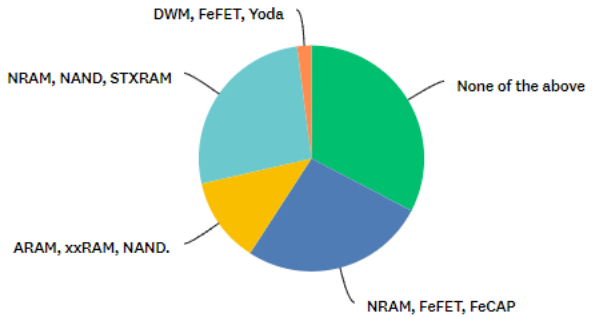
	1000 GB	2000 GB	3000 GB	5000 GB	10,000 GB	N/A	TOTAL	WEIGHTED AVERAGE
(no label)	11.54% 9	28.21% 22	12.82% 10	7.69% 6	5.13% 4	34.62% 27	78	2.49

Question this year about solid state technologies.

2022

Which 3 new Emerging Memory Technologies are expected to be delivered in the next 5 Years

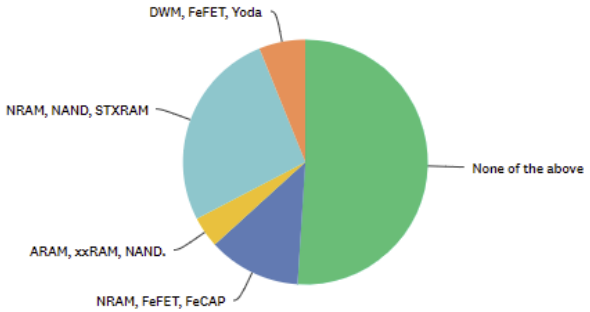
Answered: 49 Skipped: 11



ANSWER CHOICES	RESPONSES	
None of the above	32.65%	16
NRAM, FeFET, FeCAP	26.53%	13
ARAM, xxRAM, NAND.	12.24%	6
NRAM, NAND, STXRAM	26.53%	13
DWM, FeFET, Yoda	2.04%	1
TOTAL		49

2021

Answered: 49 Skipped: 18



Second year for this question.
Vs. 2021
Claims that NRAM, NANS, STXRAM
And
NRAM, FeFET and FeCAP
Are potential new technologies
.. Or “none of the above”