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# Flat Panel Display Market & Technology Outlook

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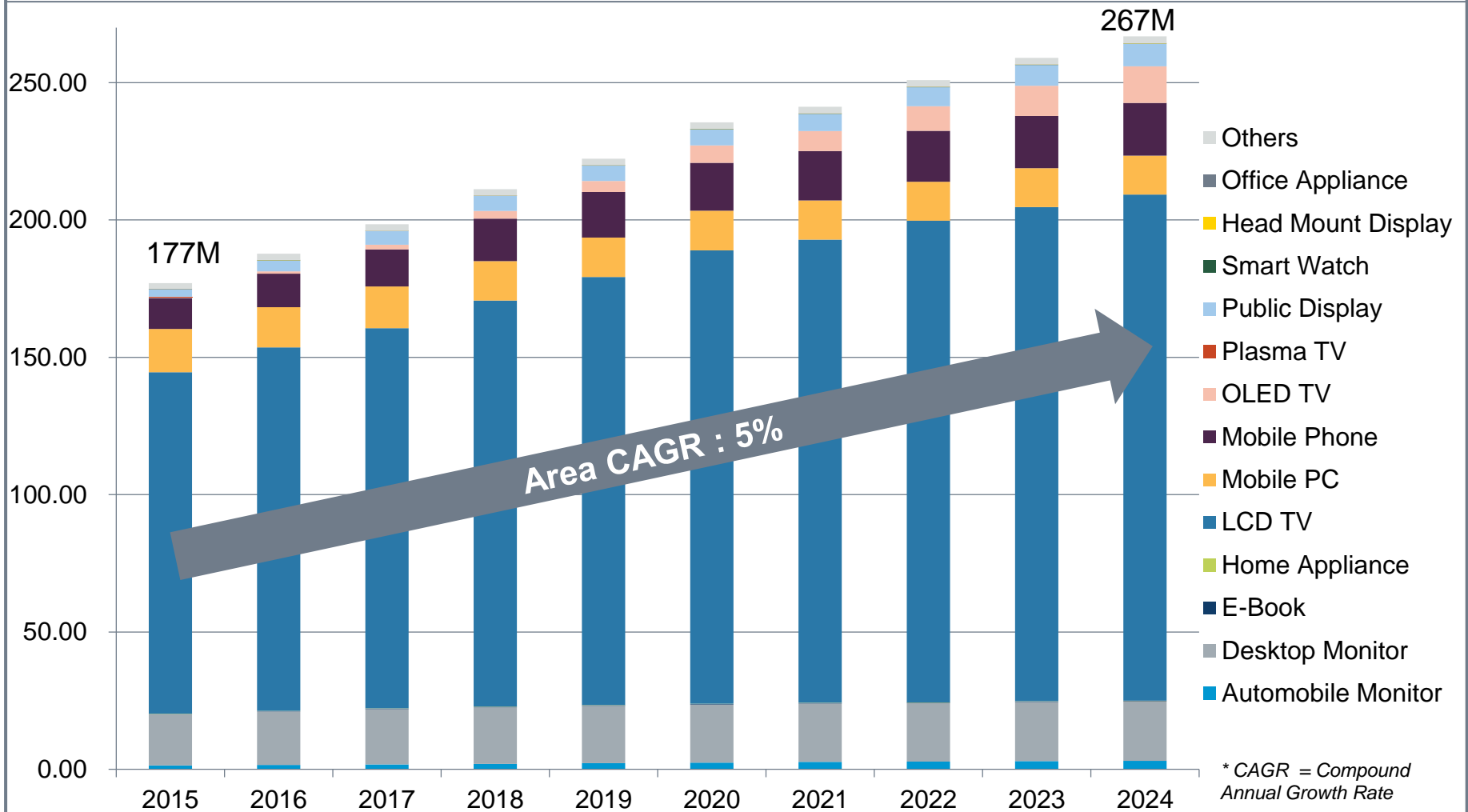
## Outlines

- **1. Flat Panel Display Market Outlook**
- **2. New Investment & Supply Demand**
- **3. Mobile, Flexible & OLED**
- **4. Display Supply Chain**
- **5. Conclusion**

# 1. Flat Panel Display Market Outlook

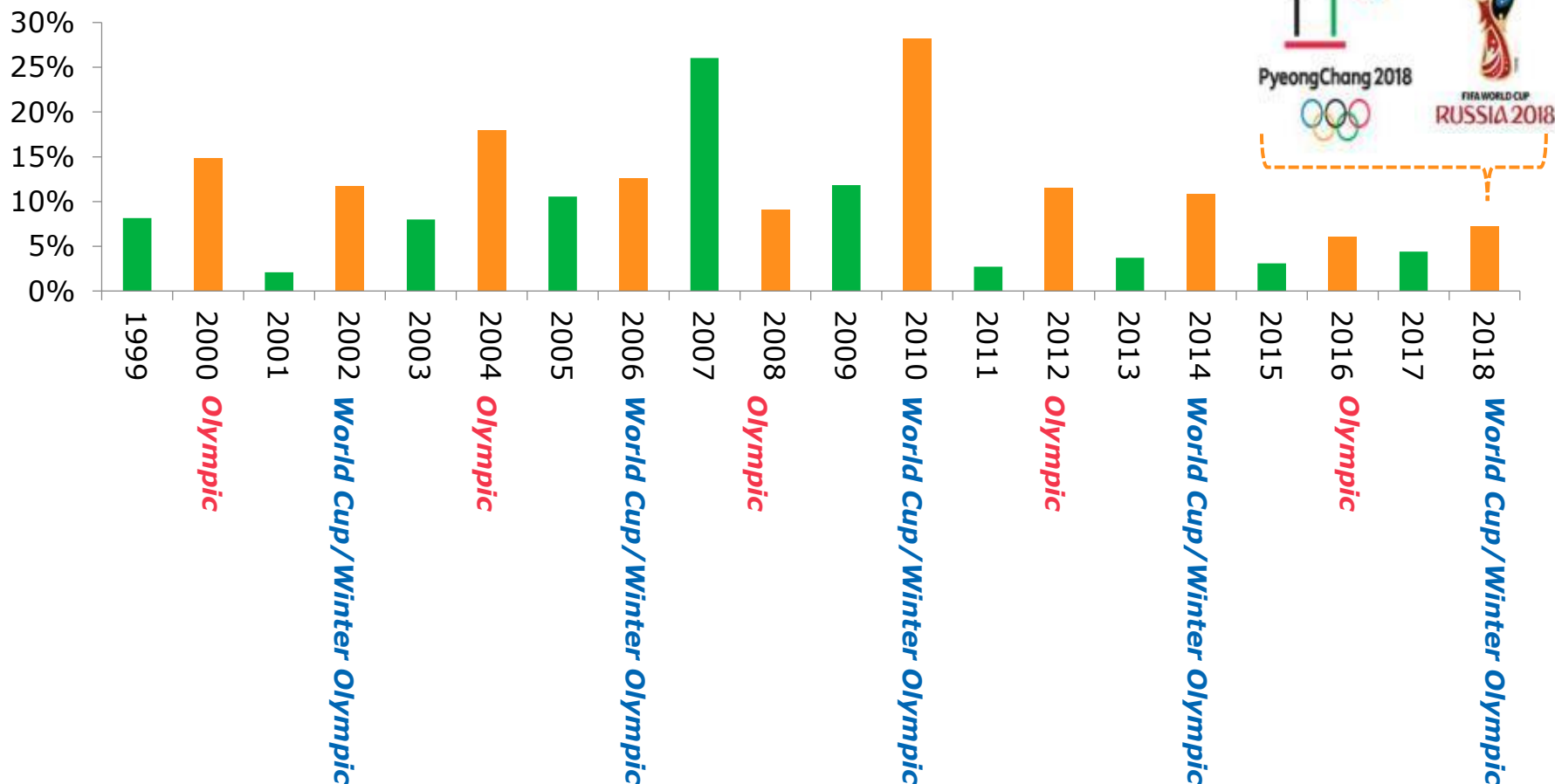
# Demand Driven By TV Area & New Applications

Display Long Term Forecast ( Area Base, Million Square Meters ) 2015 – 2024 ( 10 years )



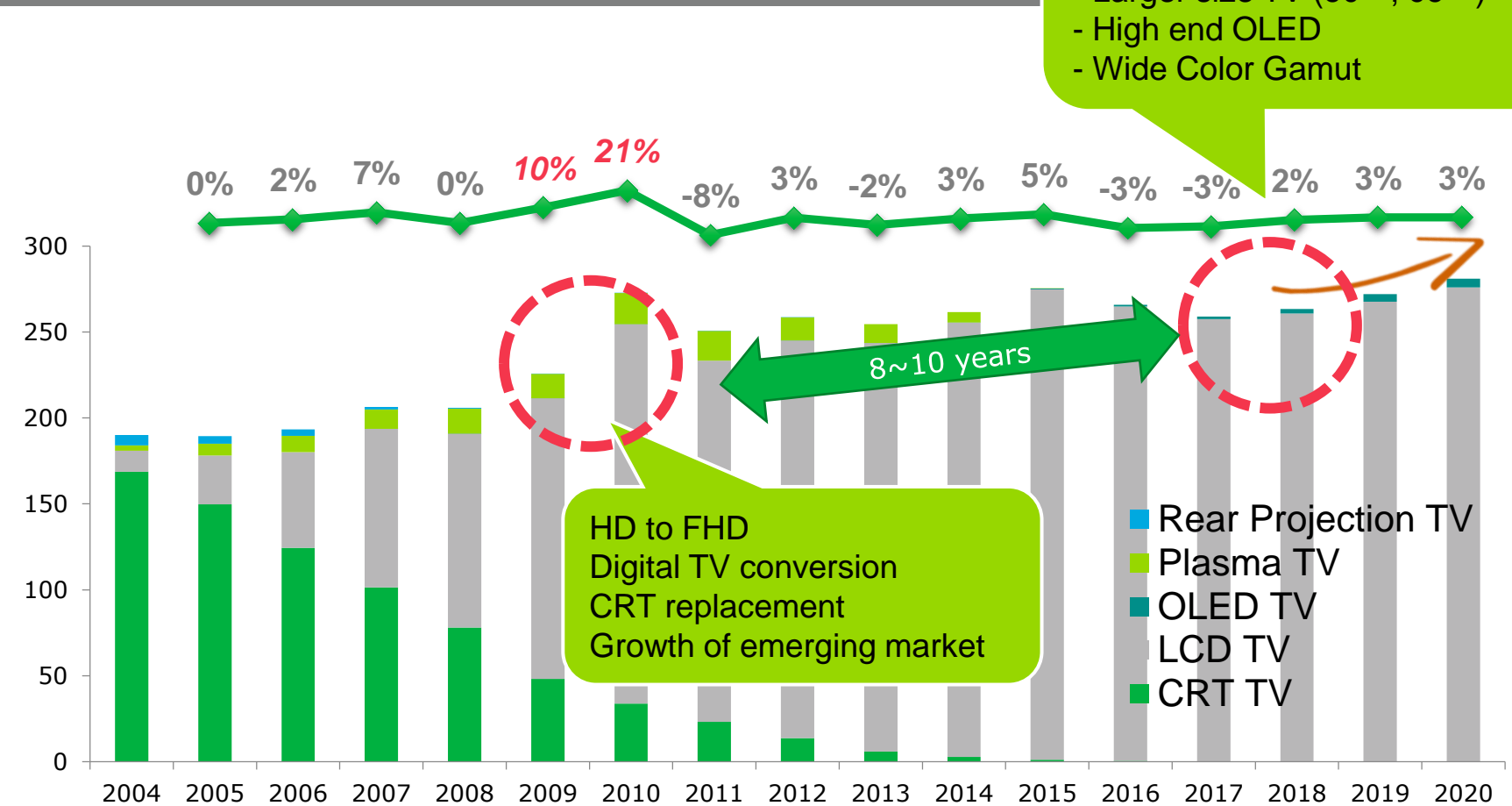
# Sport Events Have a Positive Effect on Display Market

Annual growth of Display shipment area



# TV Replacement Cycle is Coming

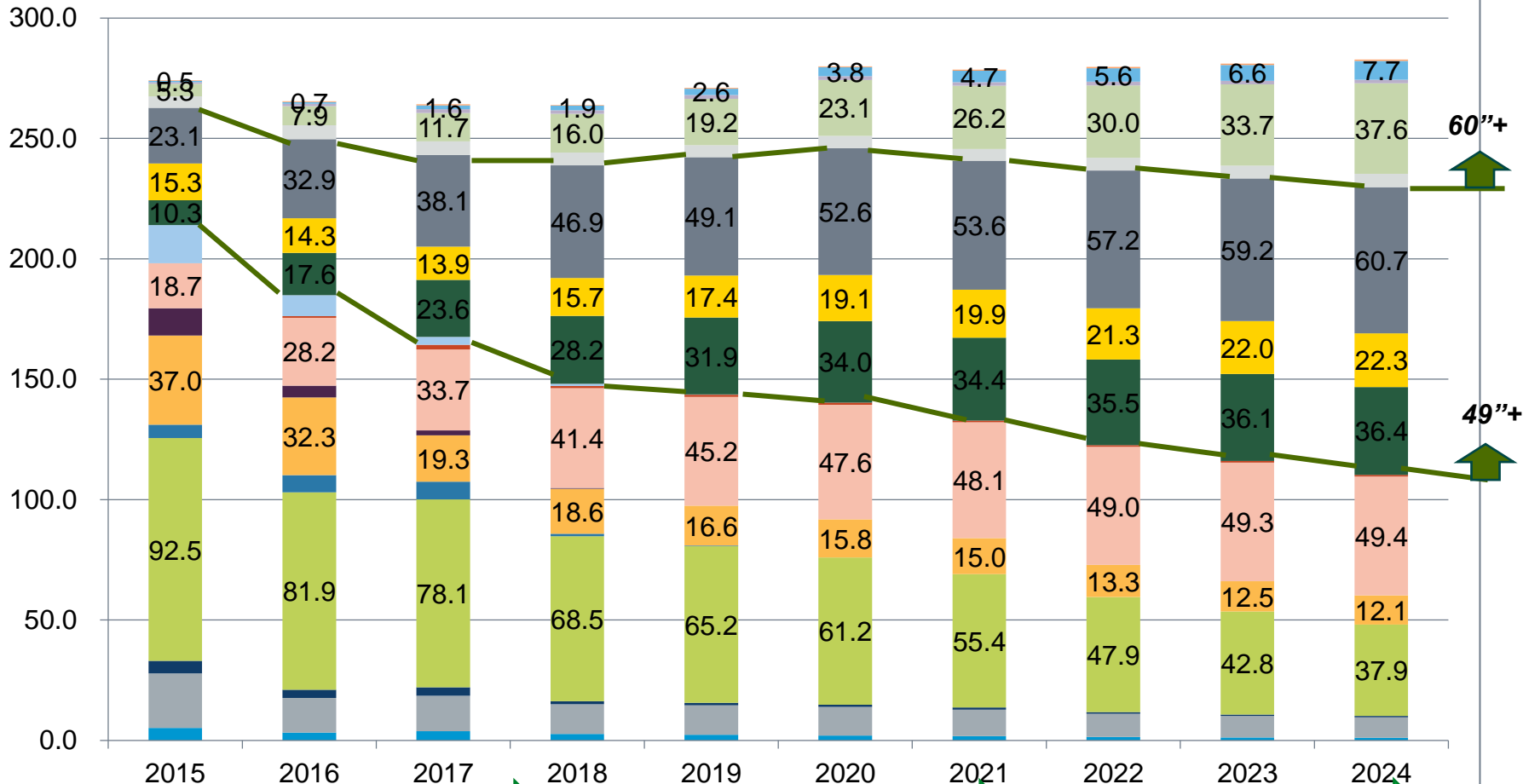
TV Display Shipment and Annual Growth Rate



# LCD TV & OLED TV Panel Size Forecast

LCD TV & OLED TV Panel Forecast (Million Units)

77" and above 75" 70" 65" 58"/60" 55" 50" 49" 46"~48" 45" 43" 42" 40" 39" 32" 28"/29" 23.6" <23.6"



Gen8 Shift to 43"/49"/55"      More Gen8.6 , Gen10.5 MP      More Gen10.5

60"+  
49"+

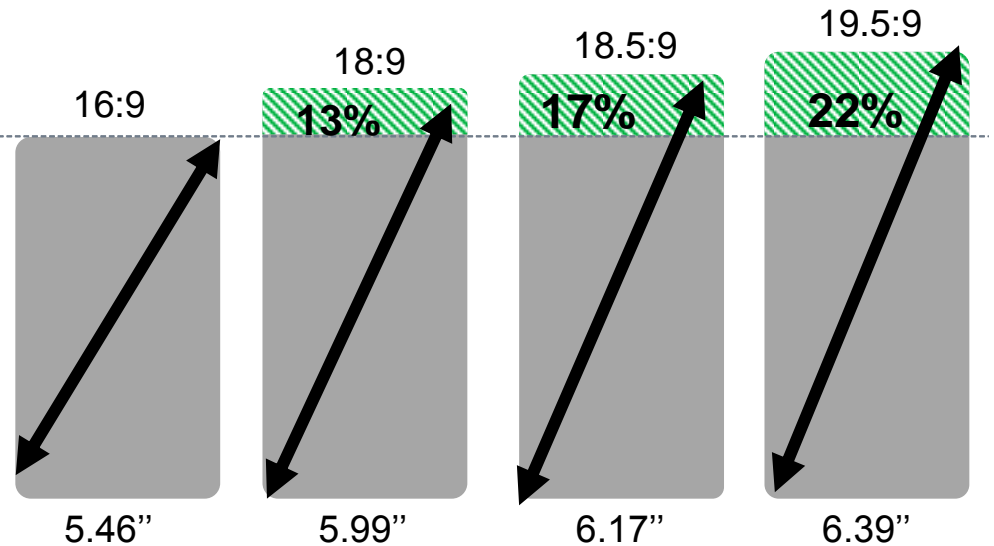
# Full Screen's Advantages for Area Growth

## • Display size

- > With the wide screen design, the average size will increase significantly and help 6"+ category shipment to grow

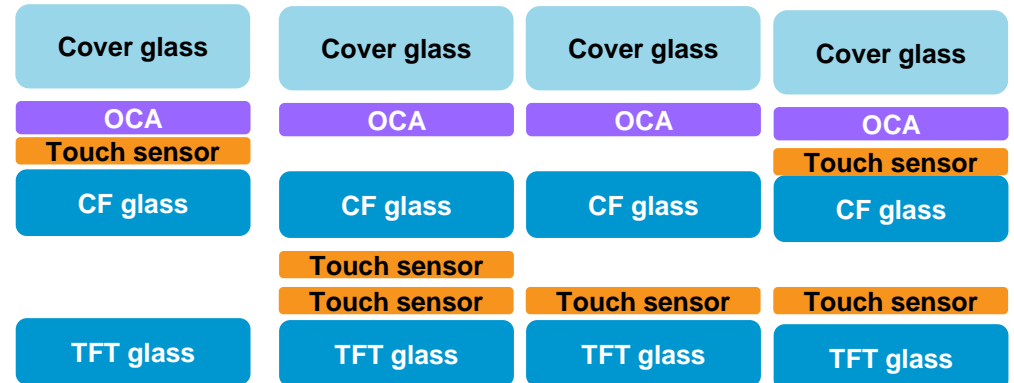
## Display area

- > The significant benefit will be the fast increasing area demand, the yield rate challenge in the initial stage will also be helpful for supply demand balance



## • Embedded touch solution

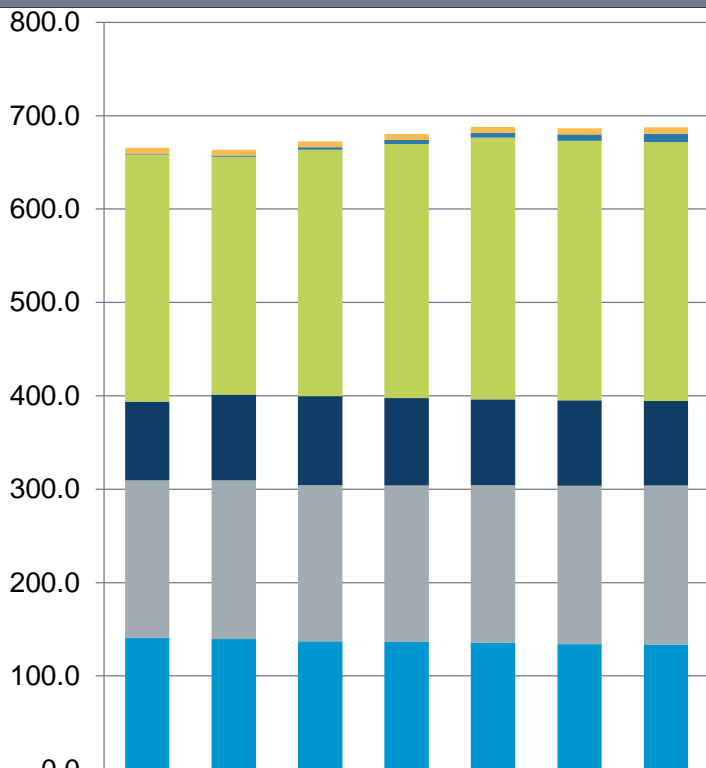
- > Most of LCD panel makers considering embedded touch solution like full in-cell for the wide screen, that helps panel makers revenue increase.
- > The TDDI (Touch Display Driver Integration) also rise.



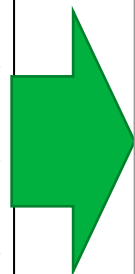


# Large Area Panel Demand Forecast (July'17 vs. January'18)

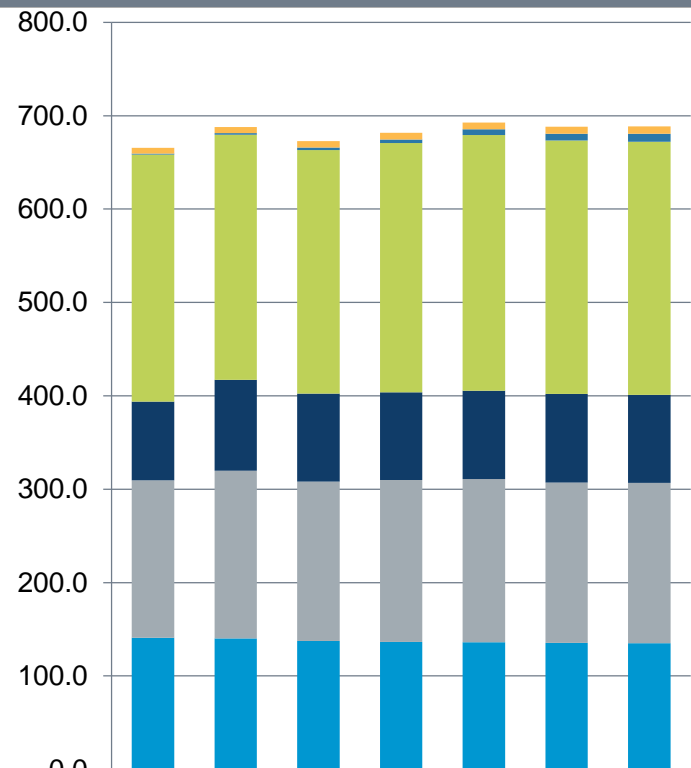
July 2017 Forecast (Unit base, Million Units)



	2016	2017	2018	2019	2020	2021	2022
Public Display	6.3	5.9	6.1	6.2	6.3	6.6	6.7
OLED TV	0.9	1.6	2.7	4.5	5.2	6.8	8.8
LCD TV	264.5	254.5	264.0	272.3	280.1	278.2	277.4
Tablet PC	84.4	91.9	95.4	93.3	92.1	91.3	90.3
Notebook PC	168.7	169.9	167.2	167.8	168.9	169.6	170.5
Desktop Monitor	140.9	139.6	137.1	136.3	135.3	134.1	133.7



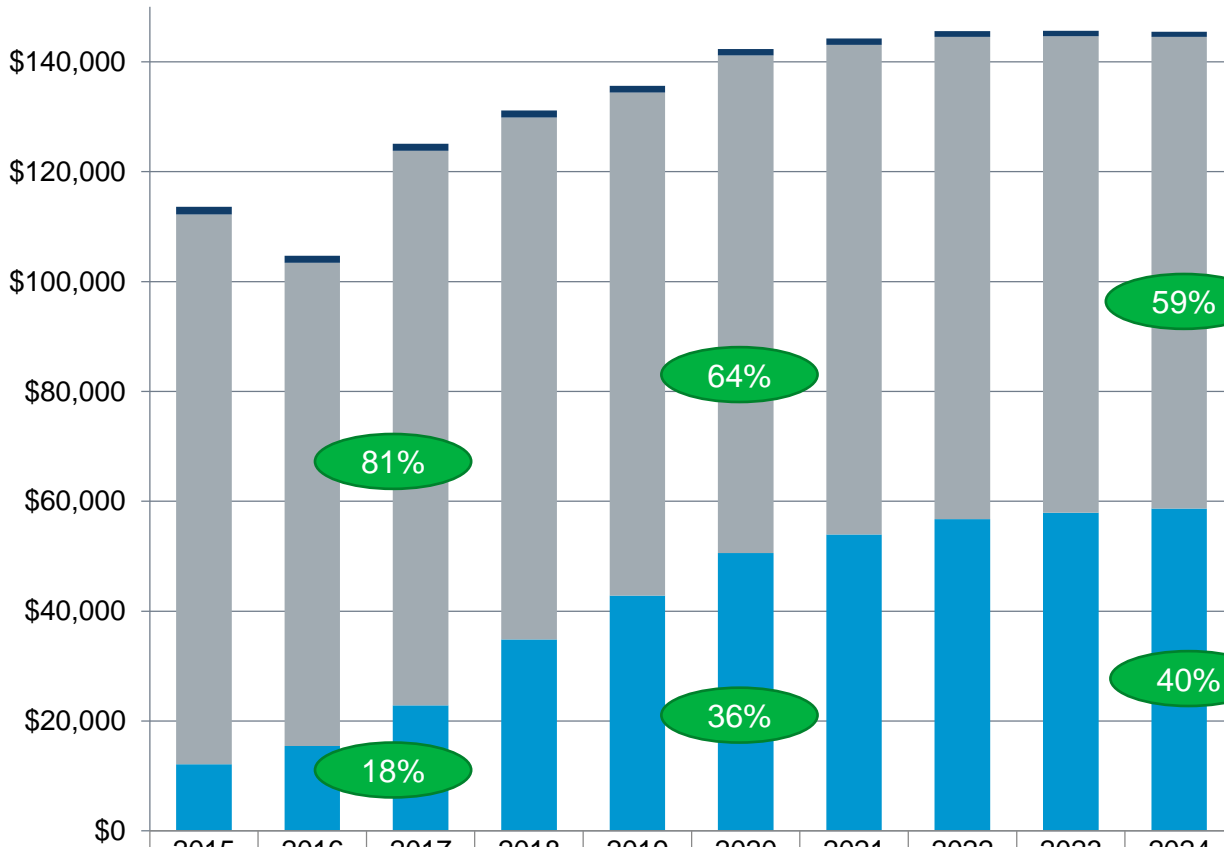
January 2018 Forecast (Unit base, Million Units)



	2016	2017	2018	2019	2020	2021	2022
Public Display	6.3	6.6	6.7	6.9	7.1	7.4	8.0
OLED TV	0.9	1.7	2.9	4.0	6.3	7.1	8.6
LCD TV	264.5	262.5	260.9	266.9	273.7	271.4	271.1
Tablet PC	84.4	97.1	94.2	94.0	94.8	95.0	94.3
Notebook PC	168.7	179.8	170.6	173.2	174.5	171.7	171.6
Desktop Monitor	140.9	140.1	137.5	136.6	136.3	135.5	135.1

# LCD and OLED Revenues

Flat Panel Display Revenues (Million USD)

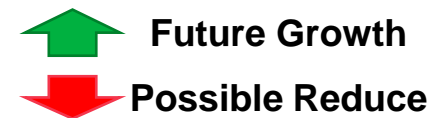


- TFT LCD Revenues Decline
  - (1). Panel price erosions
  - (2). PC panel demand fall
  - (3). Open Cell percentage
- AMOLED Revenues Growth
  - (1). OLED TV growth
  - (2). Full screen display smartphone
  - (3). Flexible/Curve mobile phone
  - (4). China and Korea investment in new capacity
  - (5). Extension to more applications
- Others = DLP, LCoS, PMLED, VFD, EPD

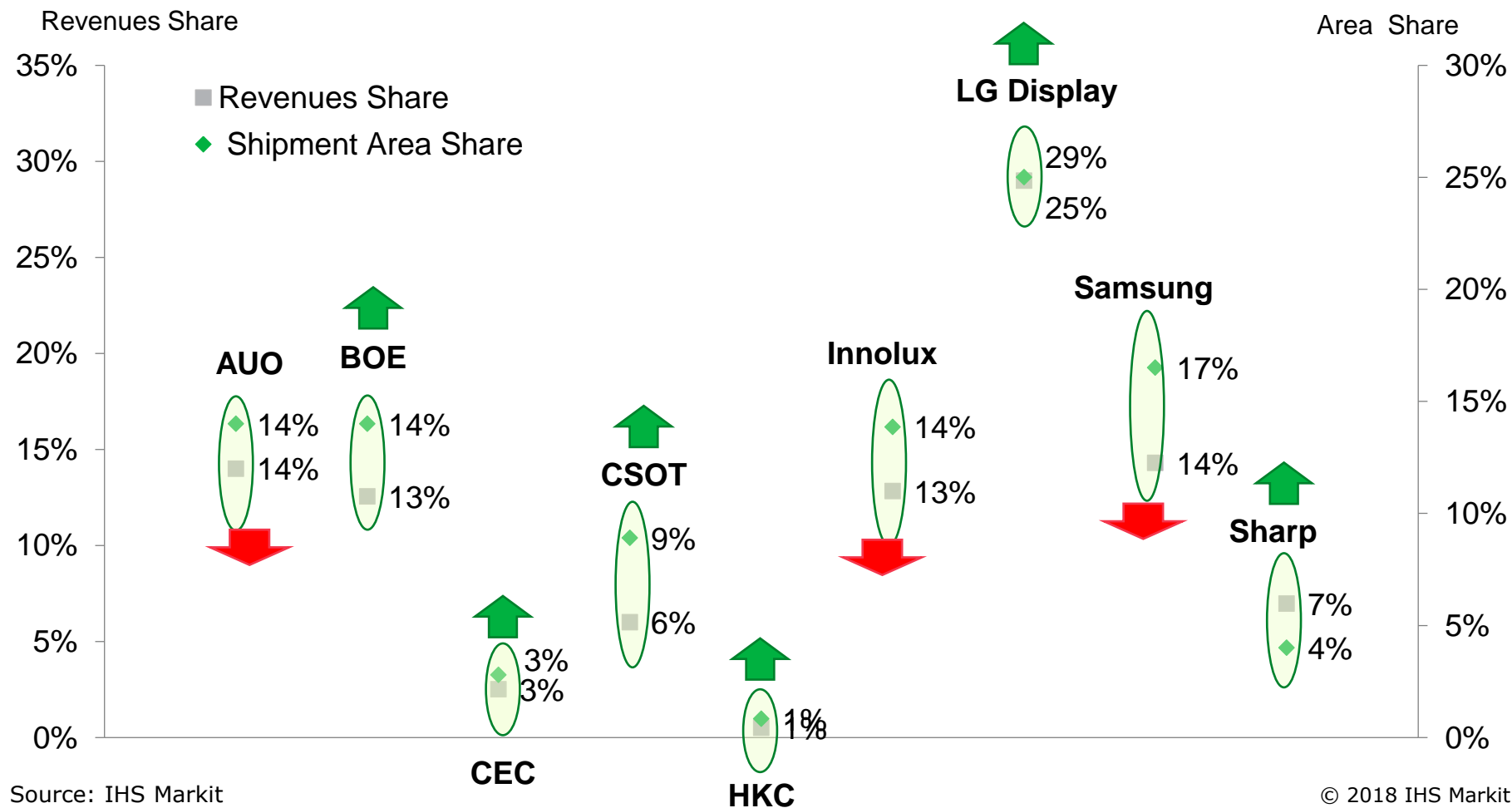
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Others	\$1,378	\$1,299	\$1,261	\$1,250	\$1,218	\$1,173	\$1,128	\$1,005	\$977	\$948
TFT LCD	\$100,0	\$87,94	\$100,9	\$95,02	\$91,57	\$90,55	\$89,15	\$87,81	\$86,76	\$85,83
AMOLED	\$12,15	\$15,46	\$22,88	\$34,86	\$42,82	\$50,59	\$53,94	\$56,74	\$57,91	\$58,67

## 2. New Investment & Supply Demand

# Large Area Display Panel Makers Position

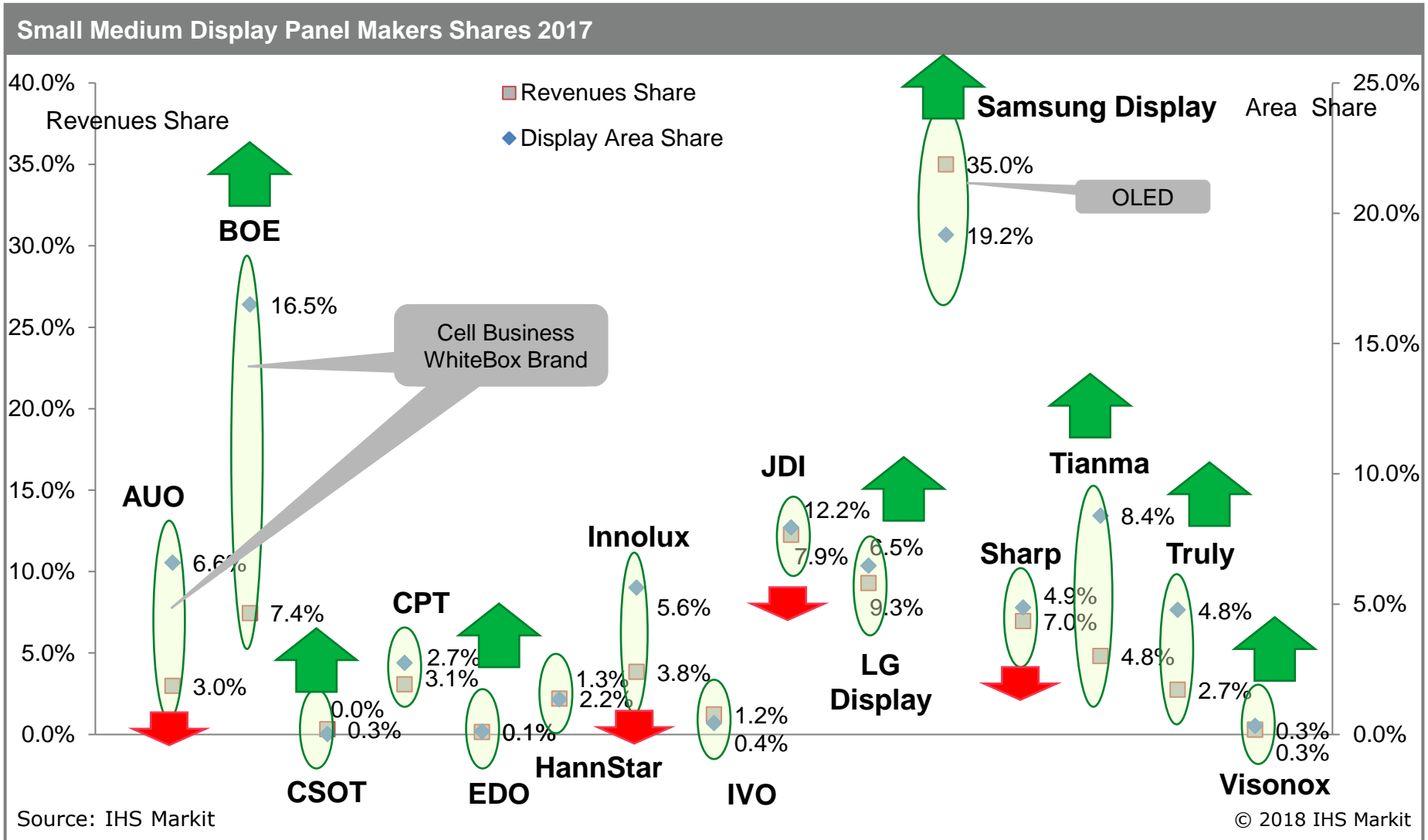


Large Area Display Panel Makers Shares 2017



# Small Medium Display Panel Makers Position

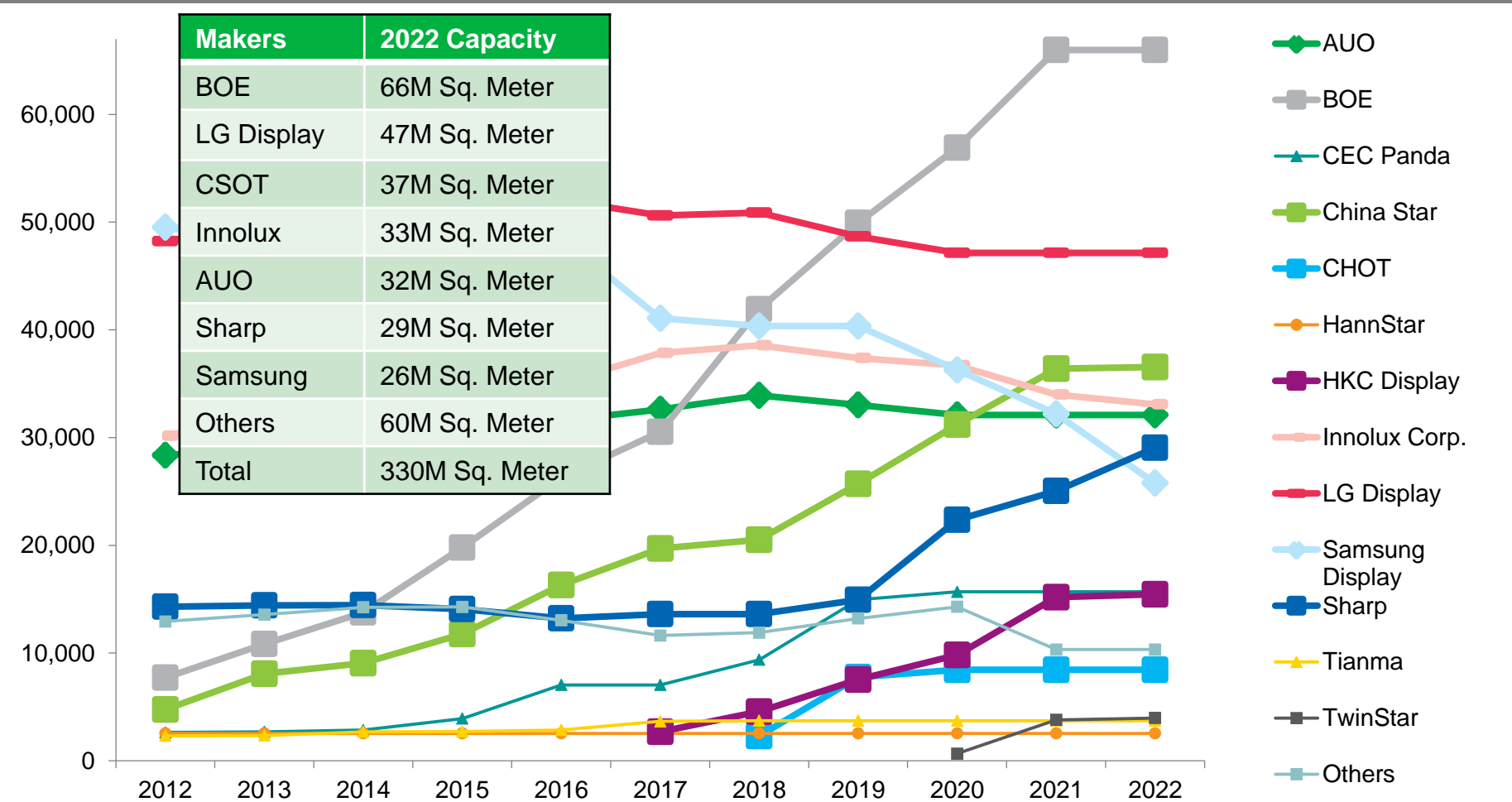
 Future Growth  
 Possible Reduce



# TFT LCD Capacity Ranking

• By Nationality , China makers : 44% in 2022

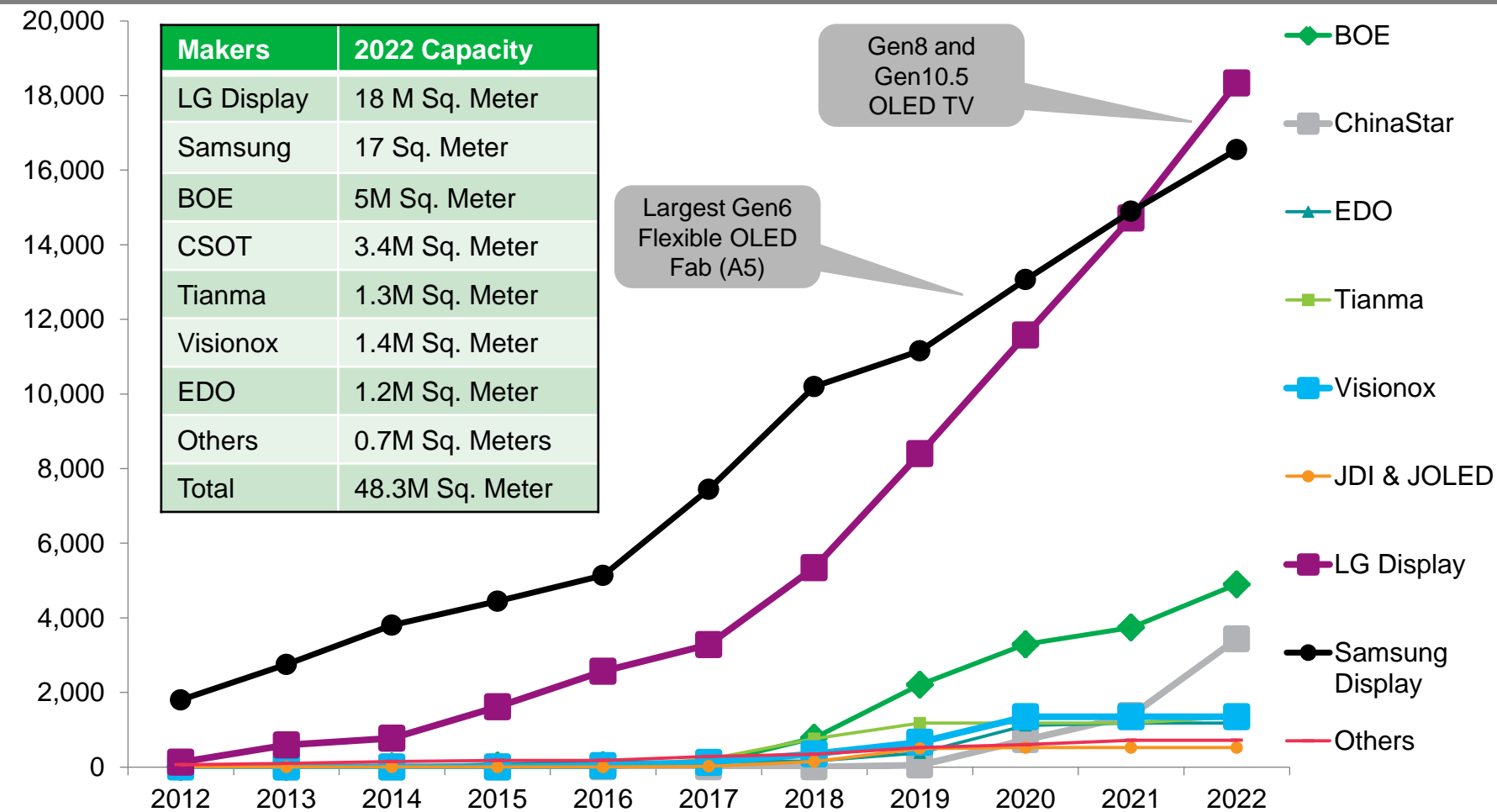
TFT LCD Capacity By Panel Makers (1,000 m<sup>2</sup>) Based on Capacity, not considering the loading and yield



# AMOLED Capacity Ranking (Including RGB and WOLED)

- By Nationality , China makers : 25% in 2022

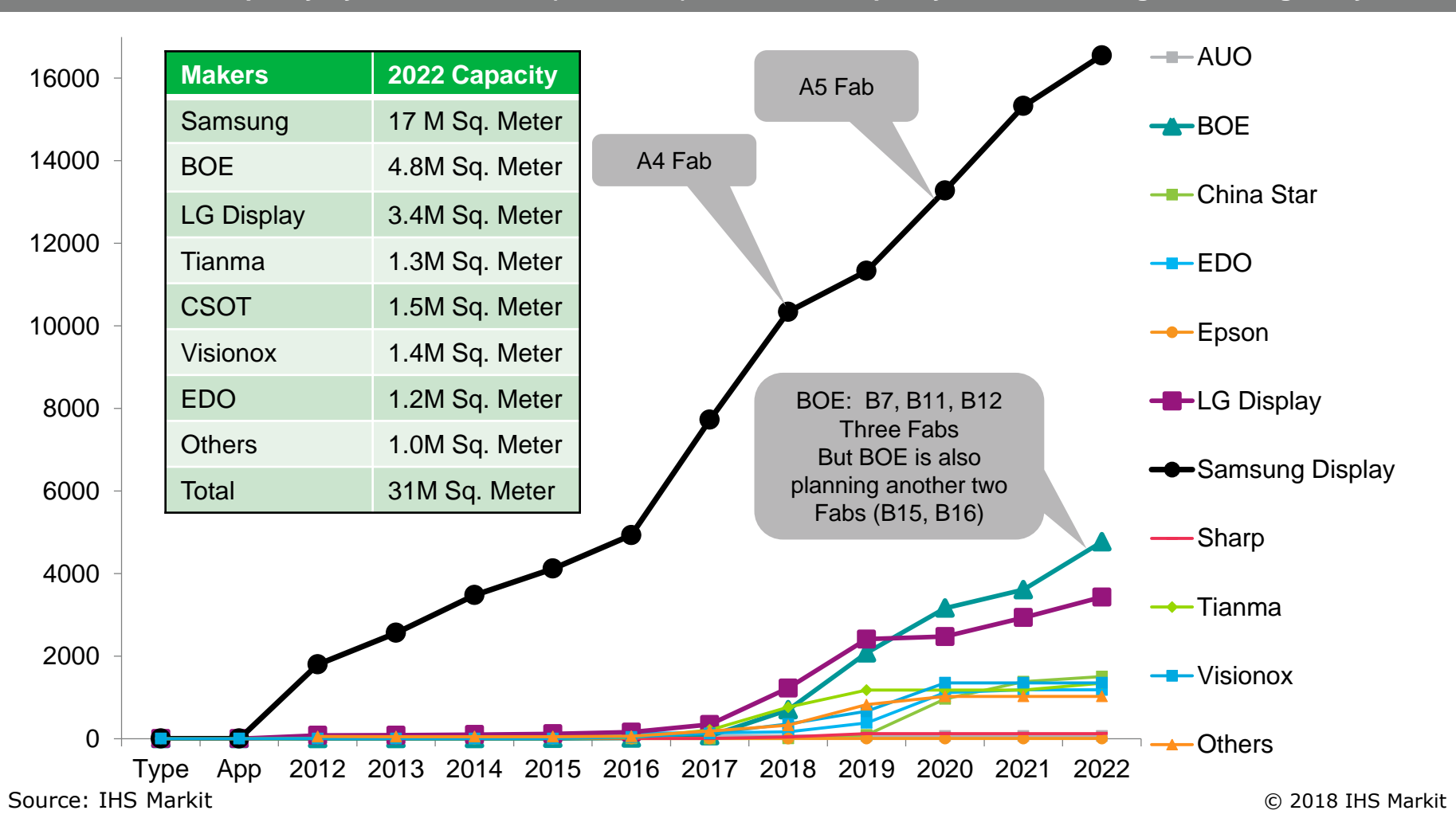
AMOLED Capacity By Panel Makers (1,000 m<sup>2</sup>) : Based on Capacity, not considering the loading and yield



# Mobile RGB AMOLED Capacity Ranking

- By Nationality , China makers : 32% in 2022

Mobile AMOLED Capacity By Panel Makers (1,000 m<sup>2</sup>) : Based on Capacity, not considering the loading and yield





# Gen 8 (Gen 8.5) above fab investment in China

Gen 8+ fabs in China (January 2018)							
Status	BOE	China Star	CEC	HKC	Samsung	LG Display	Foxconn/SDP
Mass Production	Beijing (北京) B4 Gen 8 a-Si TFT	Shenzhen (深圳) T1 Gen 8 a-Si TFT	Panda Nanjing (南京) Gen 8 Oxide TFT		Suzhou (蘇州) Gen 8 a-Si TFT	Quangzhou (廣州) Gen 8 a-Si TFT	
	Hefei (合肥) B5 Gen 8 a-Si TFT	Shenzhen (深圳) T2 Gen 8 a-Si TFT					
	Chongqing (重慶) B8 Gen 8 a-Si TFT			Chongqing (重慶) HKC Gen 8.6 a-Si TFT			
	Fuqing (福清) B10 Gen 8 a-Si TFT						
Ramping Up	Hefei (合肥) B9 (Gen 10.5)						
Under Construction		Shenzhen (深圳) T6 Gen 11 (10.5)	Panda Chengdu (成都) Gen 8.6+ Oxide TFT	Chuzhou (滁洲) Gen 8.6 a-Si TFT		Guangzhou (廣州) Gen 8.5 Oxide+WOLED	Guangzhou (廣州) SDP Gen 10.5 a-Si/Oxide TFT
			Caihong Xianyang (咸陽) Gen 8.6				
Planning	Wuhan (武漢) B17 Gen 10.5 a-Si TFT/Oxide+WOLED	Shenzhen (深圳) T7 Gen 11 (10.5) a-Si TFT/Oxide+WOLED	?	Mianyang (綿陽)? Gen 10.5	?		
							New ramp-up in 2018

By 2022  
China will have

- 9 a-Si/Oxide Gen8
- 4 a-Si/Oxide Gen8.6
- 5 Gen10.5 (Gen11)
- 1 OLED Gen8

Total **19** fabs

# Gen5.5 above Investment in China :a-Si, LTPS, Oxide

Gen 5.5+ fabs in China(January 2018)									
Status	BOE	China Star	CEC	Tianma	AUO	CPT	EverDisplay	Visionox	Holitech
Mass Production	Ordos (鄂爾多斯) B6 LTPS+OLED Gen 5.5 <Rigid>		Panda Nanjing (南京) a-Si Gen 6	Shanghai (上海) LTPS+OLED Gen 5.5 <Rigid>			Shanghai (上海) Fab 1 OLED Gen 4.5 <Rigid >	Gen5.5 Kunshan (昆山) LTPS+OLED <Rigid>	
	Hefei (合肥) B3 a-Si Gen 6	Wuhan (武漢) T3 LTPS Gen 6		Xiamen (廈門) LTPS Gen 6	Kunshan (昆山) LTPS Gen 6				
Ramping Up	Chengdu (成都) B7 LTPS+OLED Gen 6 <Rigid/Flexible>			Wuhan (武漢) LTPS+OLED Gen 6 <Flexible>		Mantix Putian (莆田) a-Si & Oxide Gen 6			
Under Construction	Mianyang (綿陽) B11 LTPS+OLED <Flexible>	Wuhan (武漢) T4 LTPS+OLED Gen 6 <Flexible>					Shanghai (上海) Fab 2 OLED Gen 6 <Flexible >	Gu'an (固安) LTPS+ OLED Gen 6 <Flexible>	Nanchang (南昌) a-Si TFT LCD Gen 5.5 <Rigid, Small Medium>
Planning	Chongqing (重慶) B12 LTPS+OLED Gen 6 <Flexible>							New Fab Gen 6 LTPS+OLED <Flexible>	
	Chengdu (福州) B15 LTPS+OLED Gen 6 <Flexible>								
	Chengdu (成都) B16 LTPS+OLED Gen 6 <Flexible>								

By 2022  
China will have

- 4 Gen4.5/5.5 LTPS+OLED
- 1 a-Si Gen5.5
- 3 a-Si/Oxide Gen6
- 3 LTPS Gen6
- 9 Gen6 LTPS + OLED/Flexible

Total **20** Fabs

New ramp-up  
in 2018

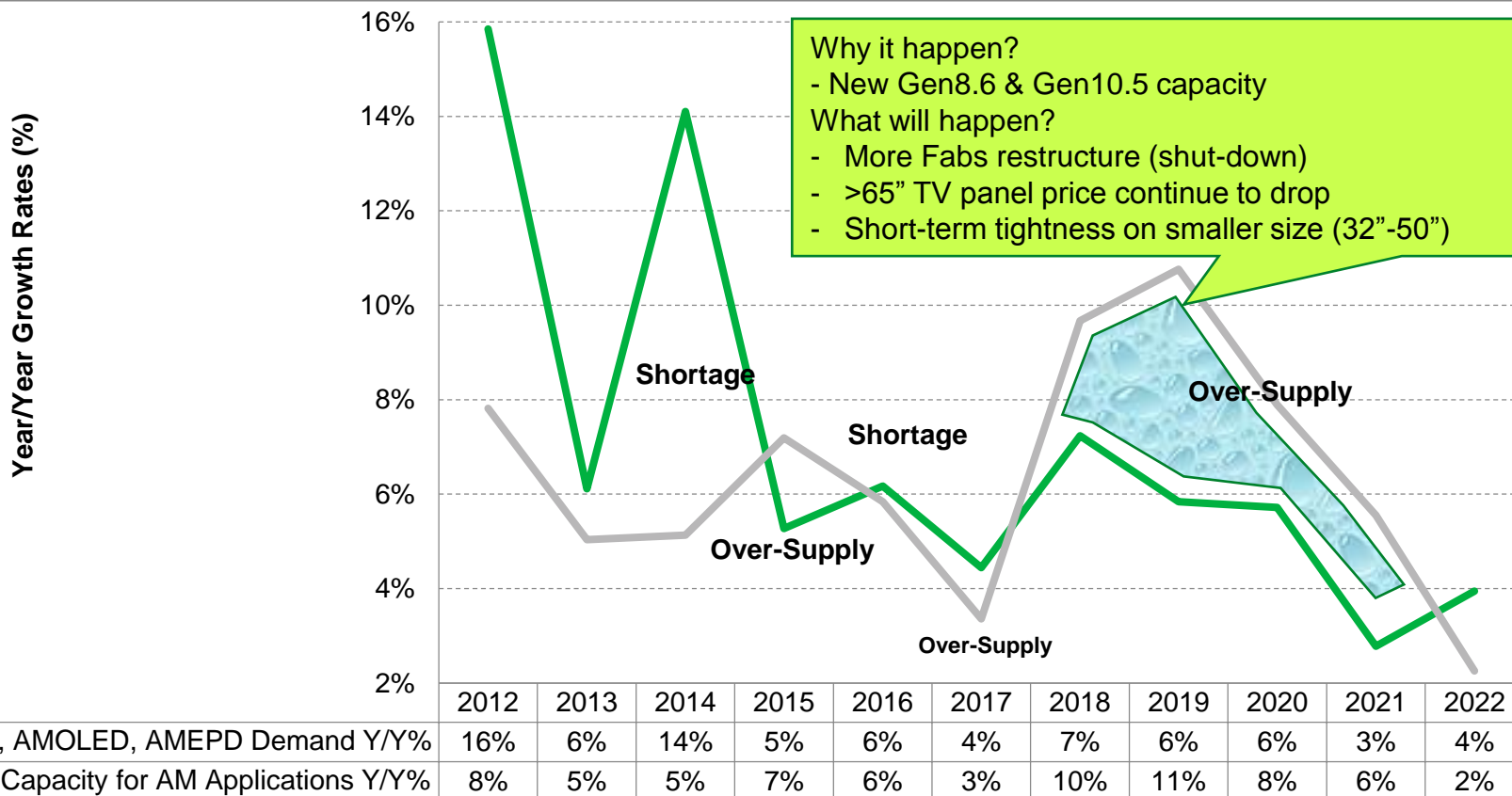


# Possible Fab Restructures (Shutdowns), 2017-18

Fab restructure schedule, 2016-2019										
Panel Maker	Fab	Gen/Glass Size	Original capacity	Tech.	Current utilization	Products	Ramp-up year	Depreciated year	Original EOL Year	Shutdown
Samsung Display	L6	Gen 5	120 K/M	a-Si	70-80%	Mobile	2003	2009	2018	Q3 2017
	L7-1	Gen 7	155 K/M	a-Si	95%	40" TV	2005	2011	2018	Dec 2016
	L7-2	Gen 7	165 K/M	a-Si	95%	TV, Monitor	2006	2011	2019	
	L8-1	Gen8	195 K/M	a-Si	82%	TV	2007	2013	2022	
AUO	L3C	Gen 3.25	60 K/M	a-Si	35%	Mobile	1999	2006	2018	
	L4A	Gen 3.5	25 K/M+ 35 K/M Touch	a-Si	50-60%	Mobile, Touch	2001	2008	2018	
Innolux	T0	Gen 4	20 K/M	a-Si+EPD	50%	Mobile	2004	2009	2018	
	T1	Gen 5	60 K/M	a-Si	60%	Mobile	2004	2010	2018	
	Fab 1	Gen 3.25	70 K/M	a-Si	60-65%	Mobile	1999	2005	2018	
	Fab 2	Gen 3.5	85 K/M	a-Si	45-50%	Mobile	2001	2007	2018	
	Fab 3	Gen 5	145 K/M	a-Si	85%	Mobile, NB	2003	2010	2018	
LG Display	P2	Gen 3.25	85 K/M	a-Si	52%	Mobile, NB	1997	2004	2017	Apr 2017
	P3	Gen 3.5	92 K/M	a-Si	50%	Mobile, NB	2000	2004	2018	Mar 2018
	P4	Gen 5	150 K/M	a-Si	65%	Mobile, NB	2002	2008	2019	Q3 2017
	P5	Gen 5	100 K/M	a-Si	62%	Mobile, NB	2002	2007	2018	Partially shift to OLED lighting
BOE	B1	Gen 5	75 K/M	a-Si	0%	Shift to E-Ink	2004	2012	2016	Shift to e-paper
	B2	Gen 4	45 K/M	a-Si	Stop	Mobile	2008	2016	2016	Under planning
CPT	T2	Gen 3.5	73 K/M	a-Si	<20%	Mobile	2001	2007	2018	
	T1	Gen 3	35 K/M	a-Si	<50%	Mobile	1999	2006		
Sharp	Taki No.2C	Gen 3.5	45 K/M	a-Si	<45%	Auto, Mobile	2000	2005	2017	
	Taki CGS B	Gen 4	95 K/M	a-Si, In-Cell	<50%	Mobile	2003	2010	2019	To OLED backplane
JDI	Mobara V3 LTPS	Gen 4	40 K/M	LTPS	<50%	Mobile	2002	2012	2016	Jan 2017
	Nanomi	Gen 5.5	22 K/M	LTPS	<50%	Mobile	2011	2017	2018	Jan 2018

# Capacity Area Growth vs. Demand

Total TFT array capacity vs. large-area and small/medium FPD module demand growth rate

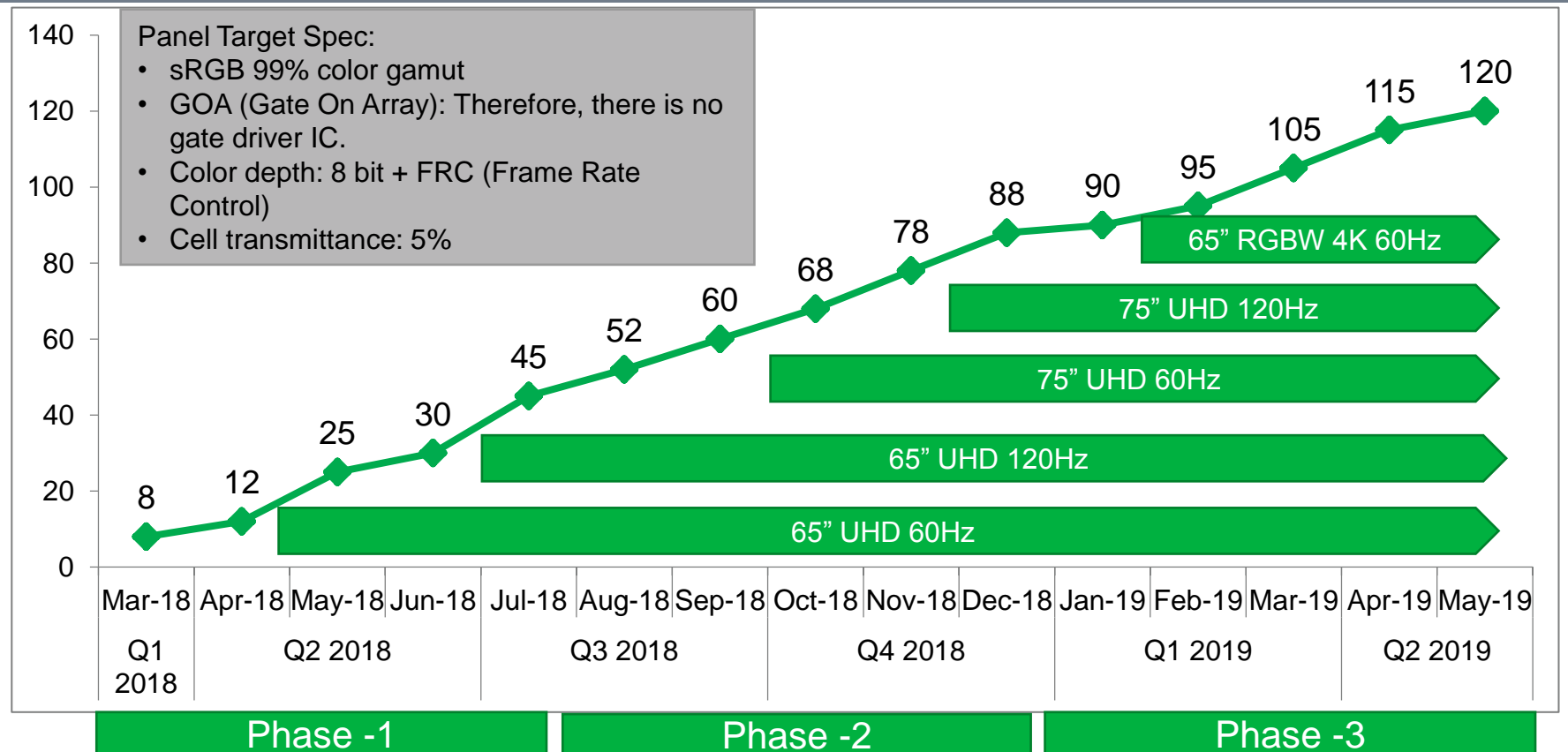


- In theory, four years over-supply (2018-2020), but in reality, it is impossible as panel makers will take action and the market will respond to the price decline. The scenario is that the first over-supply in 2018 will make the new investment postpone or the old fab shutdown.

# BOE Gen10.5 (B9) Fab Ramp Up Plan

- BOE intends to make 65" and 75" in the world's largest generation fab : B9 (Gen10.5). The biggest challenge will be the first tier TV makers' qualification on 65" UHD open cell.

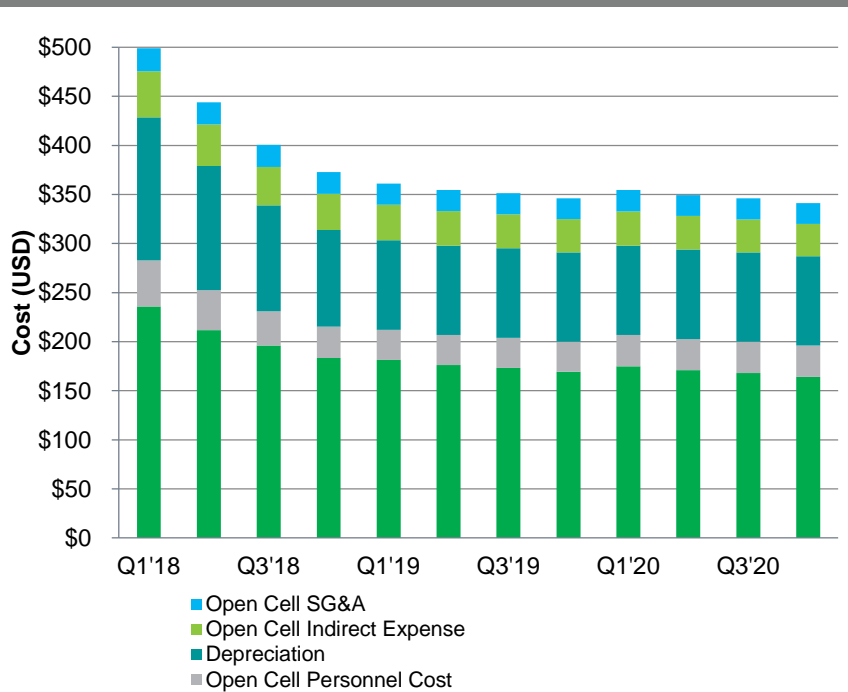
BOE Gen10.5 (B9) Fab Ramp Up Plan (Glass Substrate Input, K Substrates/Month)



# 65" Open Cell Cost \$350 in 2018 to \$250 in 2020

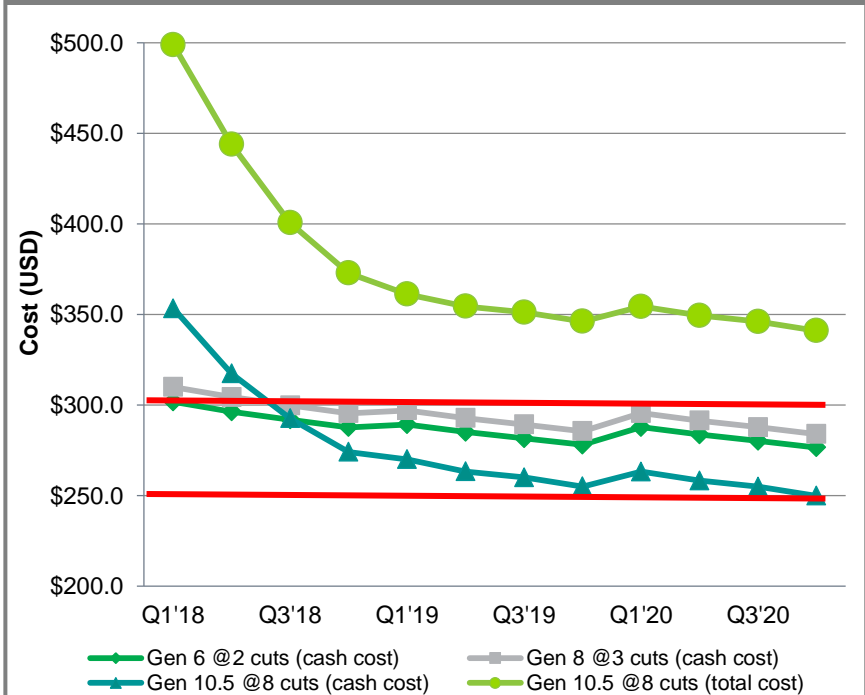
- 65-inch open cell cash cost at Gen 10.5 is expected to be at \$350 in Q1'18 and \$250 by 2020.
- While BOE has yet to prove the availability of 65-inch supply from this Gen 10.5, it proposed very aggressive price for this panel in Q2 2018. With this aggressive price offer, BOE can hardly make profit on it when comparing with the 65-inch total cost at Gen 10.5.

65" UHD LCD TV OC total cost forecast – 8 cuts at Gen 10.5



Note: 65" UHD yield assumption at Gen 10.5: Q1'18 53%, Q2'18 61%, Q3'18 72%, Q4'18 85%, 2019-2020: 85% © 2017 IHS

Cost comparison – 65" UHD LCD TV OC cost forecast at different fabs

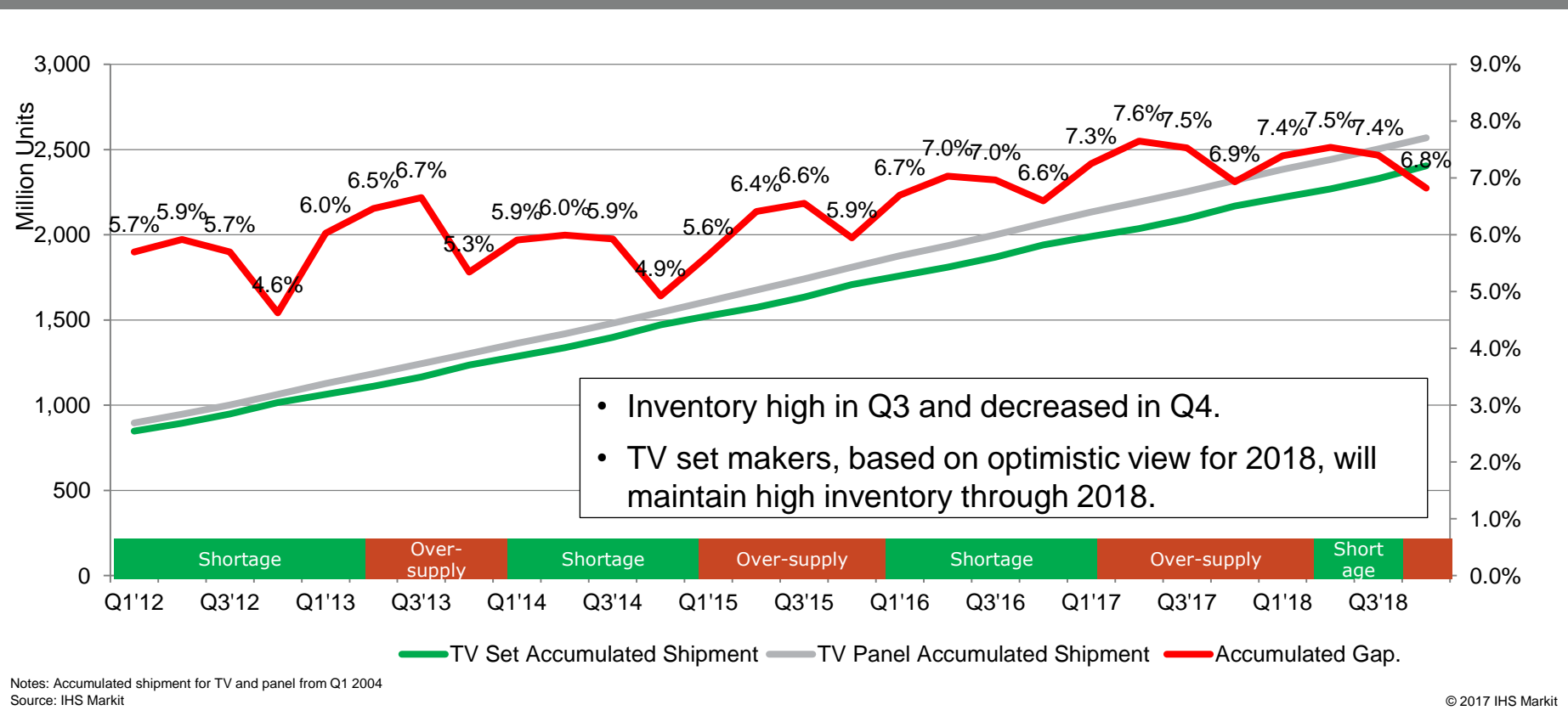


Note: 65" UHD yield assumption at Gen 10.5: Q1'18 53%, Q2'18 61%, Q3'18 72%, Q4'18 85%, 2019-2020: 85% Source: IHS Markit © 2017 IHS

# LCD TV panel/set Accumulated Gap

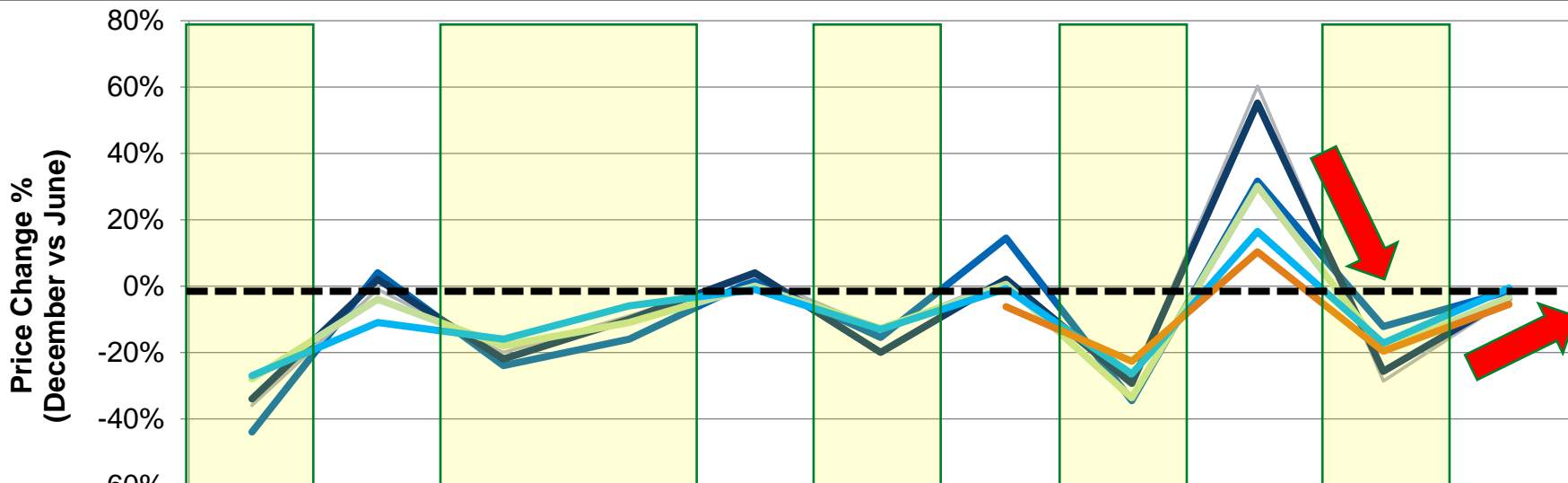
- After the inventory adjustment in Q4 2017, and the set makers' intention to remain high inventory through 2018 to respond to the good market demand, we expect some panel tightness might show up in some specific sizes, in which the panel price will stabilize, from Q2 2018 to Q3 2018. But the overall trend is still over capacity.

LCD TV module vs. set shipment comparison and gap forecast



# LCD TV Open Cell Price Change in 2H & Q1 2018

Panel price changes during H2, 2008-2018 (HD/FHD/UHD, open cell), December 2017 update



	H2 2008	H2 2009	H2 2010	2H 2011	2H 2012	2H 2013	2H 2014	H2 2015	H2 2016	H2 2017 (F)	Q1 2018 (F)
32"	-44%	4%	-24%	-16%	2%	-15%	14%	-35%	32%	-12%	-2%
40"	-36%	-1%	-20%	-9%	3%	-13%	2%	-29%	60%	-29%	-4%
42"/43"	-34%	2%	-22%	-10%	4%	-20%	2%	-29%	55%	-26%	-4%
46"/48"/49" UHD	-28%	-4%	-18%	-11%	0%	-13%	1%	-34%	30%	-19%	-3%
55" UHD	-27%	-11%	-16%	-6%	-1%	-13%	-1%	-26%	16%	-17%	-1%
65"UHD							-6%	-23%	10%	-20%	-5%

Notes: 1) 2H price erosion of historical years is based on the price change between June and December. Q1 2018 price erosion is based on the price change in the corresponding quarter (Mar'18 vs Dec'17). 2) From January 2016, prices of 49" and 55" are with the resolution of UHD.

Source: IHS Markit

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## 3. Mobile, Flexible & OLED

# Smartphone, Tablet, Notebook Display Technology

Samsung Galaxy      China brands      Apple iPhone      China Supply      Foldable

## Smartphone

Master Technology	Backplane	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
AMOLED	LTPS	17%	24%	24%	30%	36%	40%	42%	43%	43%	43%
	a-Si	50%	43%	39%	31%	29%	26%	23%	22%	21%	20%
TFT LCD	LTPS	32%	32%	37%	38%	35%	34%	35%	36%	36%	37%
	Oxide	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

## Tablet PC

Master Technology	Backplane	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
AMOLED	LTPS	2%	1%	2%	2%	3%	3%	3%	3%	4%	4%
	a-Si	94%	90%	81%	82%	81%	77%	74%	73%	71%	69%
TFT LCD	LTPS	0%	1%	1%	2%	3%	3%	3%	3%	3%	4%
	Oxide	4%	8%	16%	13%	14%	17%	19%	20%	22%	23%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

<9" tablet Decrease

## Notebook PC

Master Technology	Backplane	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
AMOLED	LTPS	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
	a-Si	99%	97%	89%	85%	83%	81%	80%	79%	77%	76%
TFT LCD	LTPS	0%	0%	0%	0%	1%	1%	1%	2%	2%	2%
	Oxide	1%	3%	10%	14%	16%	17%	18%	19%	20%	21%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Macbook

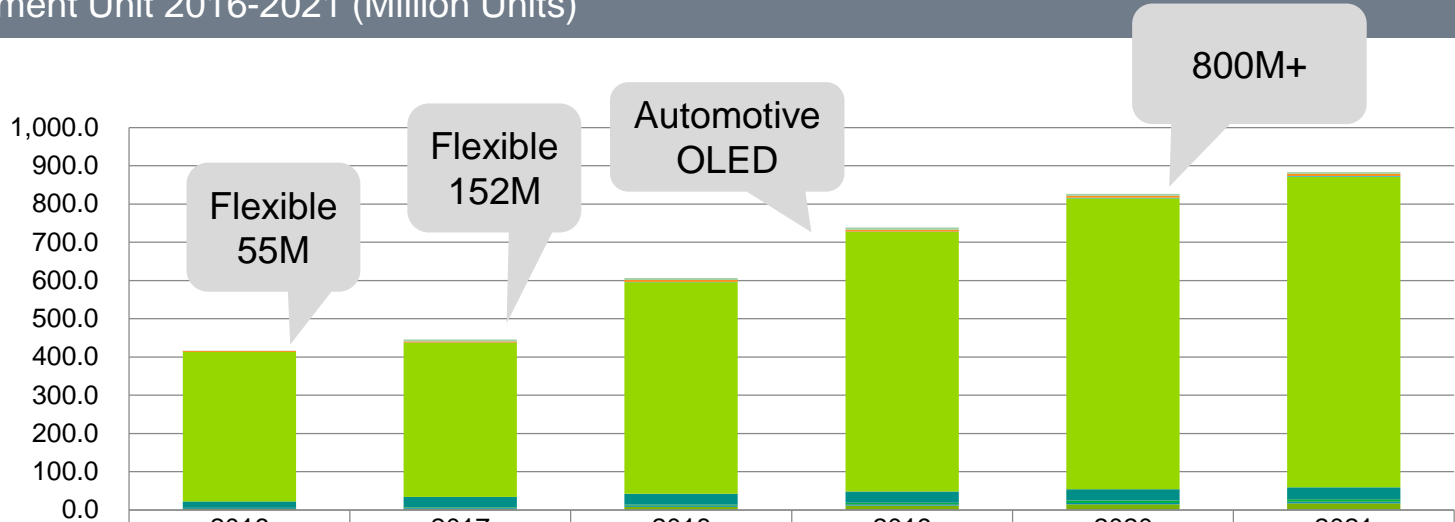
LTPS Notebook  
For better power consumption

FHD

13.3", 14", 15.4", 15.6"  
WQHD, 4Kx2K

# AMOLED Shipment : 800M in 2020

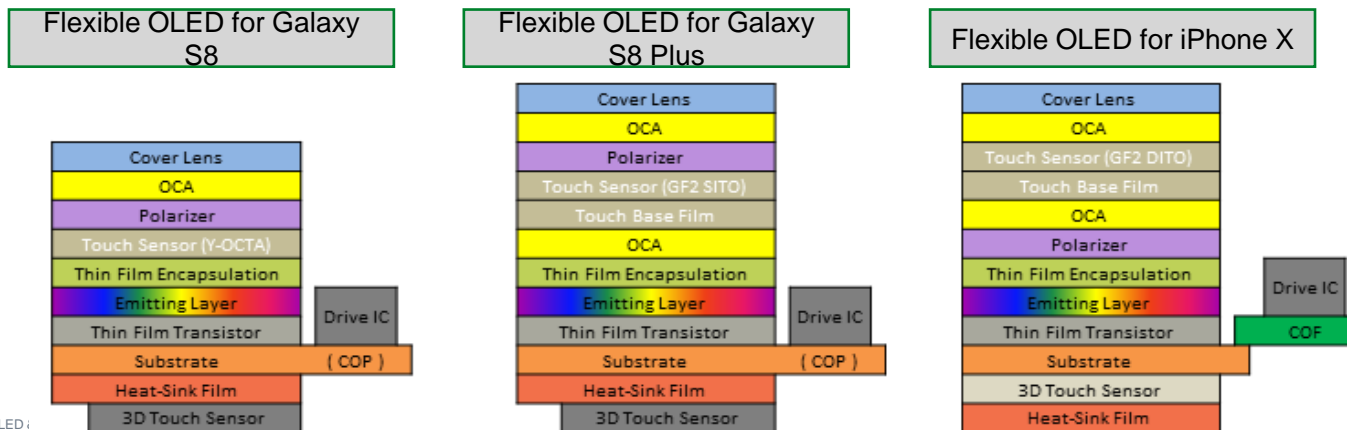
AMOLED Shipment Unit 2016-2021 (Million Units)



	2016	2017	2018	2019	2020	2021
Others	0.1	5.4	5.3	5.1	5.0	4.9
Tablet	3.0	3.4	4.5	4.9	5.3	5.8
Mobile Phone Sub Display	0.0	1.1	1.3	1.3	1.4	1.4
Smartphone	390.6	401.9	552.8	678.1	760.2	812.4
Smart Watch	16.8	26.8	28.4	29.3	29.9	30.4
Rear Seat Entertainment	0.0	0.0	0.0	0.0	0.0	0.0
OLED TV	0.9	1.7	2.9	4.0	6.3	7.1
Notebook PC	0.1	0.1	0.1	0.2	0.3	0.5
Near Eye	1.8	2.3	2.8	3.1	3.3	3.3
Head Mount Display	2.6	3.5	8.4	11.7	14.1	16.5
Digital Still Camera	0.2	0.0	0.0	0.0	0.0	0.0
Desktop Monitor	0.0	0.0	0.0	0.0	0.0	0.0
Automobile Monitor	0.0	0.0	0.0	0.4	0.8	1.3

# More Display Suppliers Opportunities For iPhone OLED

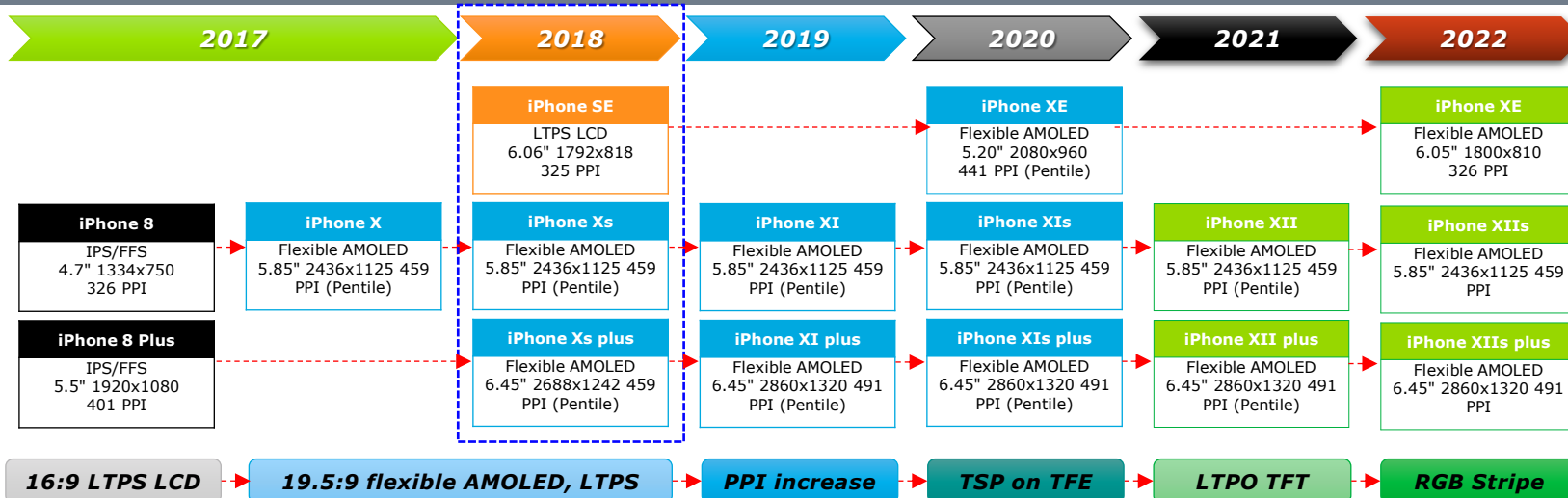
Structure Comparison of flexible AMOLED for latest smartphones



Source: IHS Markit's <AMOLED >

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Estimating Technology Roadmap of flexible AMOLED for iPhone X Series



© 2017 IHS Markit

Note : This forecast table is a estimation of IHS, not an actual roadmap of Apple.

# China OLED – Still a long way with challenges but aggressive

Samsung Display AMOLED Smartphone panel shipment (Million Units)

Customer	Substrate	2017	2018 Target
Samsung Galaxy	Flexible	68	90
	Rigid	170	150
Apple iPhone	Flexible	55	140
Others (mainly China)	Flexible	4	30
	Rigid	94	90
Total	Flexible	127	260
	Rigid	264	240
	Sum	391	500

Source: IHS Markit

© 2017 IHS

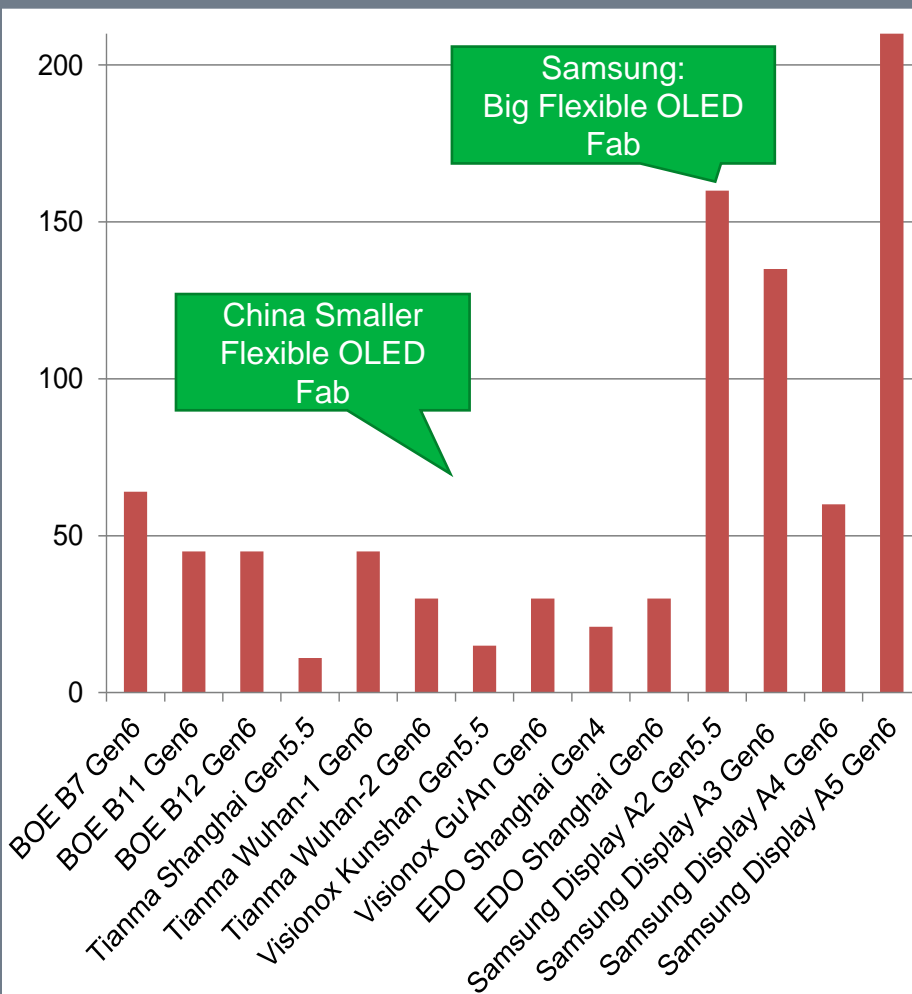
AMOLED Smartphone panel shipment (Million Units)

Supplier	OLED	2017	2018
AUO	Rigid	1	1.5
LG Display	Flexible	1.2	25
BOE	Flexible	0.1	33
EverDisplay	Rigid/Flexible	2	2
Tianma	Rigid/Flexible	1.3	10
Visionox	Rigid/Flexible	3	20
Total		8.6	91.5

Source: IHS Markit

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China OLED Fab vs. Samsung Display OLED Fab ('000 substrates Per month)



Source: IHS Markit

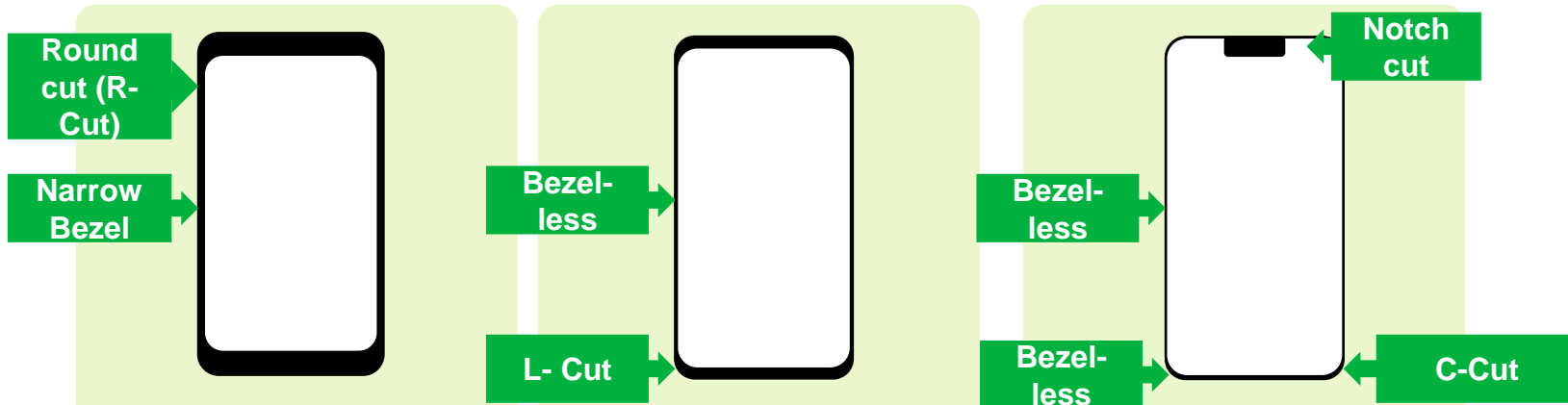
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# 2018 Smartphone Display By Brands

2018 Smartphone Brand's Business Plan by Display Technology (Million Units)

Mil. units	2016	2017(F)	2018 By Display Technology				Remark	
			2018(F)	a-Si TFT	LTPS & Oxide TFT	Rigid OLED		Flexible OLED
Samsung	310	320	321	80	30	131	80	Focus on high end
Apple	215	226	237		87		150	2 OLED model, 1 LCD
Huawei	139	153	168	60	83	15	10	"Notch" for all high end/middle end
OPPO	95	116	120	40	50	29	1	Product strategy is facing bottleneck
Vivo	81	95	100	40	25	32	3	Struggle with Inventory
Xiaomi	58	94	110	21	70	16	3	Focus on Cost and Price, More on LTPS
LG	55	56	57	30	23	0	4	
ZTE	59	50	41	20	16	4	1	Supply mainly by Module maker
Motorola	24	42	46	20	20	6	0	
Gionee	28	27	25	13	8	4	0	
TCL-Alcatel	34	22	19	7	10	2	0	
Lenovo	26	15	10	5	4	1	0	
Meizu	22	17	15	3	9	2	1	
Sony	15	16	16	6	10	0	0	
Others	237	232	277	130	120	17	10	Through agencies and module (IDH) makers
Total	1,400	1480	1562	475	565	259	263	
Panel	1,609	1,690	1,828	← Display is usually 15% higher than set				

# Full Screen Evolution and Requirements



<b>Lin-up</b>	<ul style="list-style-type: none"> <li>Mid-end</li> </ul>	<ul style="list-style-type: none"> <li>Mid to high-end</li> </ul>	<ul style="list-style-type: none"> <li>premium</li> </ul>
<b>Requirement</b>	<ul style="list-style-type: none"> <li>HD+/ FHD+</li> <li>Round cut</li> <li>Narrow bezel (L/R)</li> <li>COG (Chip on Glass)</li> <li>New Driver IC</li> </ul>	<ul style="list-style-type: none"> <li>HD+/ FHD+ /WQHD+</li> <li>Round cut / L Cut</li> <li>Bezel less (L/R)</li> <li>Narrow bezel (U/D)</li> <li>COF/two metal COF</li> <li>new Driver IC</li> </ul>	<ul style="list-style-type: none"> <li>FHD+ / WQHD+</li> <li>Round cut / C- Cut</li> <li>Bezel less (U/D/R/L)</li> <li>Notch cut</li> <li>COP (Chip on Plastic)</li> <li>new Driver IC</li> </ul>
<b>LCD vs AMOLED</b>	<ul style="list-style-type: none"> <li>Both LCD and AMOLED are available to make.</li> <li>Cost competitiveness is key factor</li> </ul>	<ul style="list-style-type: none"> <li>Both LCD and AMOLED are available to make.</li> <li>But, demand for edge-curved will be to Flexibe AMOLED</li> </ul>	<ul style="list-style-type: none"> <li>Both of LCD and AMOLED are available. But more challenges in LCD for backlight and cutting process, and cost</li> </ul>

# iPhone in 2018

iPhone in 2018 by IHS Estimation



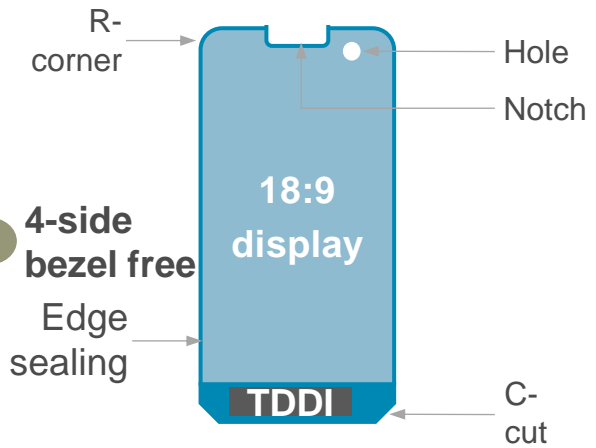
Source: IHS Markit

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# Smartphone Display Key Word: 2017 Full Screen, 2018 : Notch

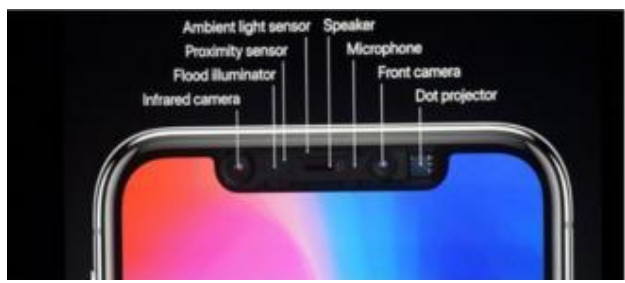
## 1 Non-rectangular shape



## 2 4-side bezel free

Edge sealing

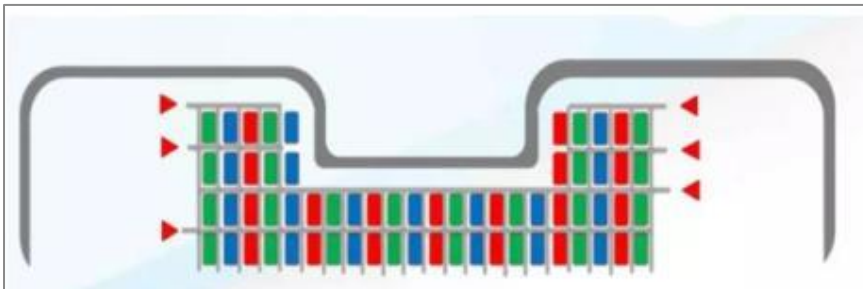
## 3 Front Camera 3D sensors



Process	Requirement	Status	Cost Adder
TFT LCD Array	<ul style="list-style-type: none"> <li>Free shape seal dispenser</li> <li>Free shape cutting for glass and fine edge polishing</li> </ul>	<ul style="list-style-type: none"> <li>(Laser cutting) Equipment getting ready in Q1 2018</li> </ul>	<ul style="list-style-type: none"> <li>Photo Mask NRE fee if required special design</li> </ul>
LCD Polarizer	<ul style="list-style-type: none"> <li>Free shape cutting and fine edge polishing</li> </ul>	<ul style="list-style-type: none"> <li>Ready but new investment needed</li> </ul>	
TFT Backlight	<ul style="list-style-type: none"> <li>Free shape cutting</li> <li>LED 1803/COB package for slim boarder and to reduce halo effect</li> <li>Assembly challenge</li> </ul>	<ul style="list-style-type: none"> <li>LCD module maker purchase the equipment</li> <li>COB (LED Chip on Board) is under development.</li> <li>Apple book special LED for Notch LCD</li> </ul>	<ul style="list-style-type: none"> <li>+\$3~6 USD → &lt;\$3 (for reference design)</li> <li>* R cut/C cut degree will impact the yield rate and cost</li> </ul>
Driver IC	<ul style="list-style-type: none"> <li>18.x:9/19.x:9/20.x:9 support</li> <li>COG new IC for 3.5mm down boarder</li> </ul>	<ul style="list-style-type: none"> <li>Support ready from 4Q'17</li> </ul>	
Hardware	<ul style="list-style-type: none"> <li>Smaller sized front camera</li> <li>3D sensors</li> </ul>	<ul style="list-style-type: none"> <li>Some may not adopt 3D sensor, but still use notch for front camera, speaker, etc.</li> </ul>	\$15-20+ USD

# Notch for Android products

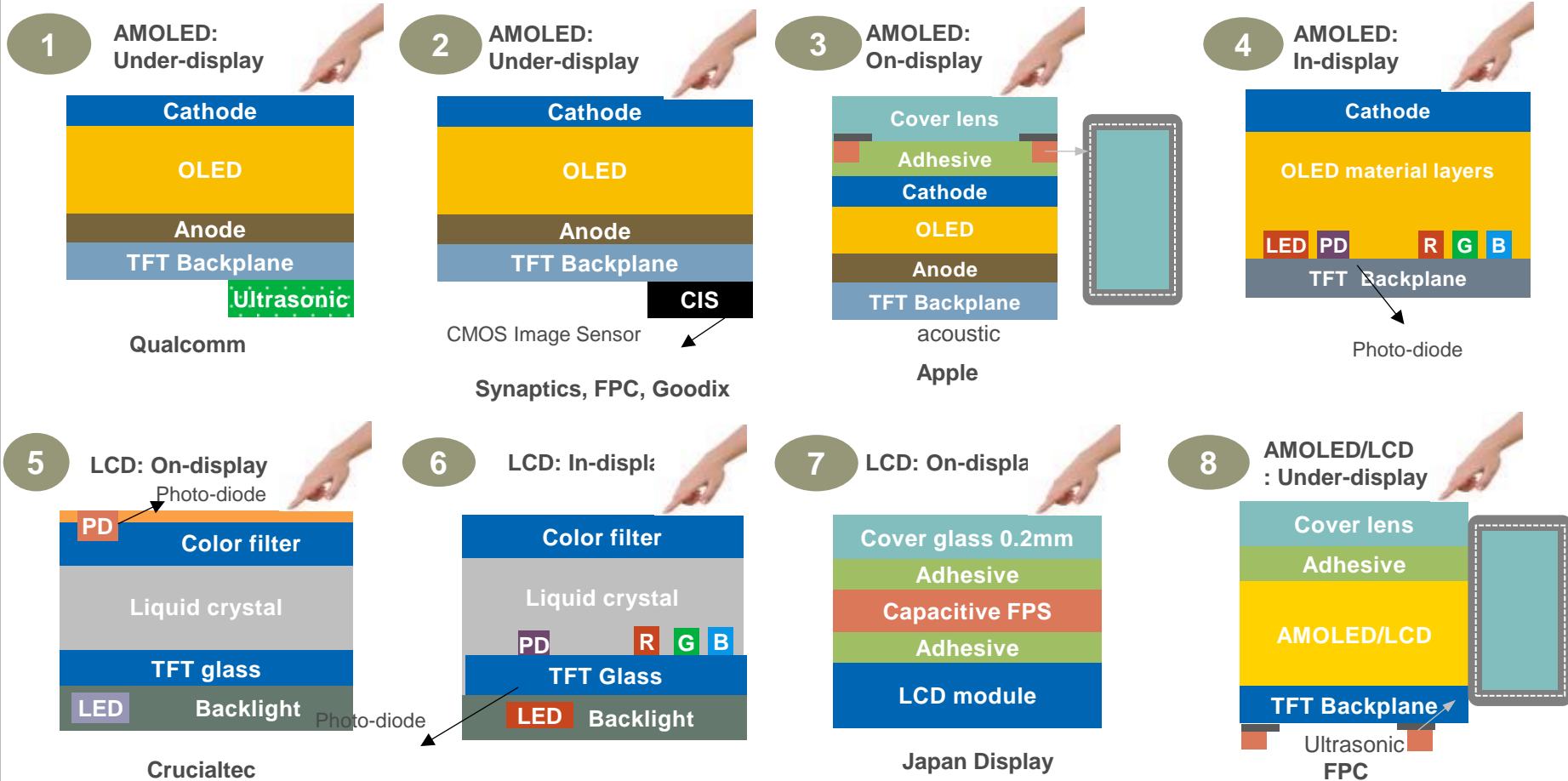
Technology	a-Si TFT	LTPS LCD	LTPS LCD	AMOLED Rigid	AMOLED Flexible
Resolution	HD+	HD+	FHD+	FHD+/QHD+	FHD+/QHD+
Planning sizes	<ul style="list-style-type: none"> <li>Under discussion and preferring “standard notch design” for lower cost.</li> <li>5.84-inch, 5.96-inch, 6.04-inch, 6.25-inch, etc.</li> </ul>	<ul style="list-style-type: none"> <li>Majority are private mold (5.x/6.x) for differentiation</li> <li>Many are centered at : 5.84-inch and 6.18-inch</li> </ul>	<ul style="list-style-type: none"> <li>Special customized (5.x/6.x)</li> <li>Sizes are : 5.6x-inch, 5.8x-inch, 6.2x-inch, 6.3x-inch, etc.</li> </ul>	<ul style="list-style-type: none"> <li>Under discussion</li> </ul>	
Status	<ul style="list-style-type: none"> <li>Will begin from whitebox brands from 1Q’18.</li> </ul>	<ul style="list-style-type: none"> <li>Major brands will have customized version first and then move to other brand from 2Q’18.</li> </ul>	<ul style="list-style-type: none"> <li>Notch FHD+ AMOLED will be available from 2Q’18.</li> <li>Samsung Display is planning to promote FOD (fingerprint on display) + Notch QHD+ solution for Chinese brand makers for flagship in 2H’18.</li> </ul>	<ul style="list-style-type: none"> <li>The photomask expenses for flexible notch is too high.</li> <li>Currently, Samsung Display only offer S8/S8+ w/o notch flexible sizes.</li> <li>Notch with Flexible OLED is for Apple only.</li> </ul>	



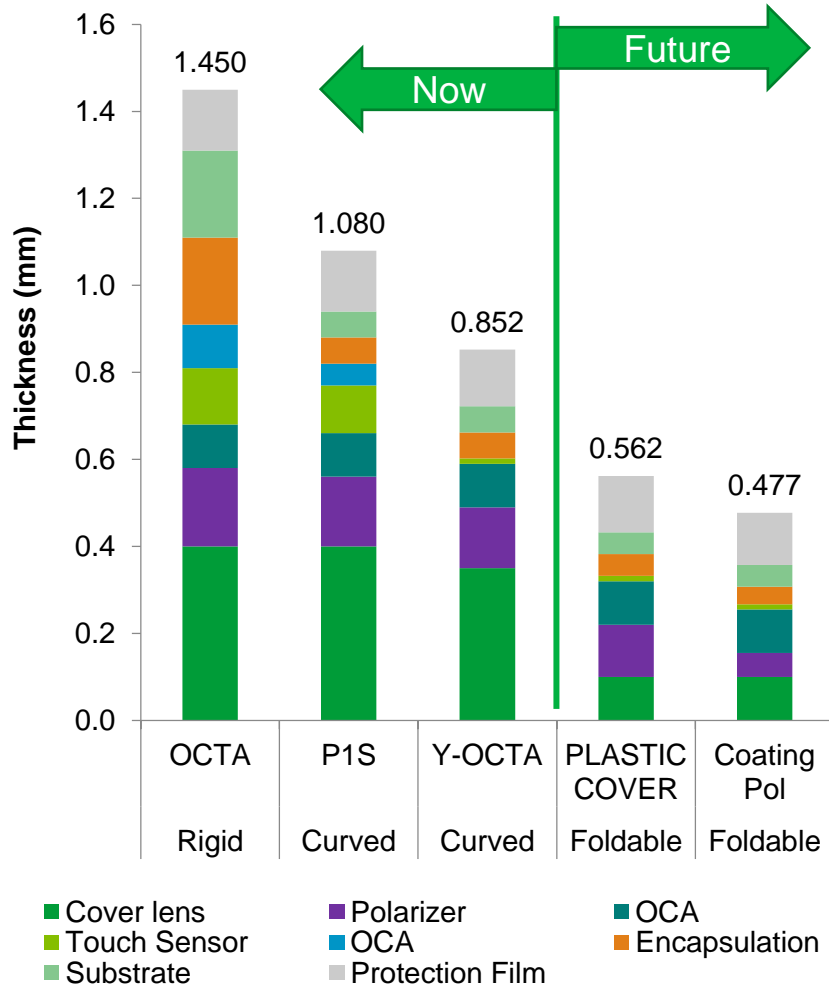
# Display-based Fingerprint

- Display-based issues: Light path, SNR (Signal-to-noise ratio) and display's modification
- Four technologies : Active Capacitance, CMOS Image Sensor, Optical Imaging (Photo-diode), Ultrasound

## Display-based fingerprint solutions



# Foldable Display

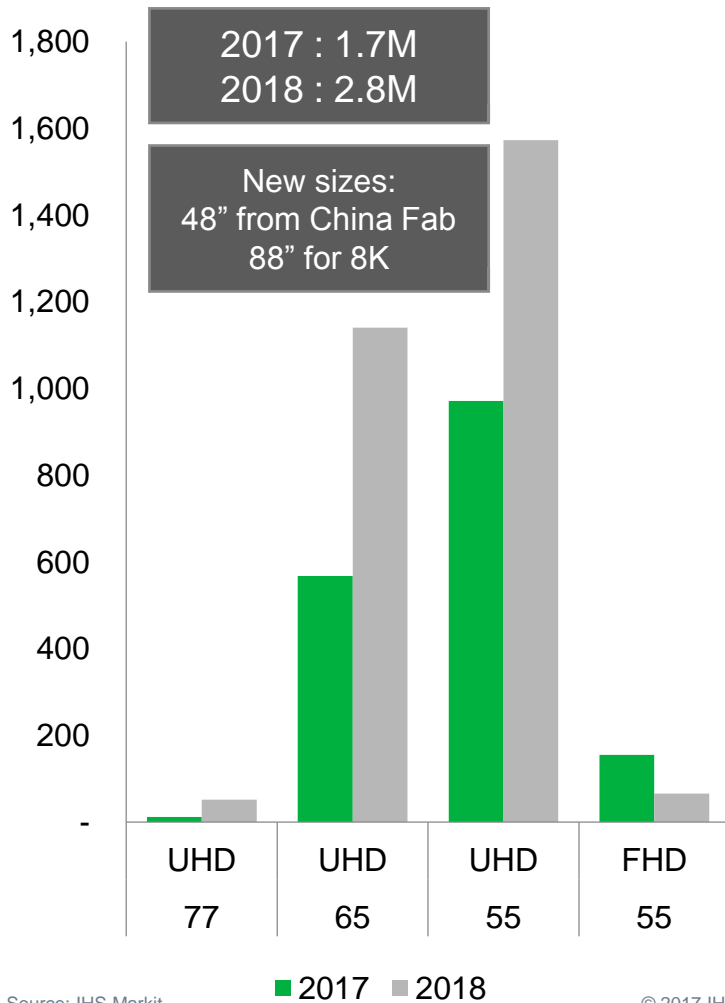


Source : IHS Report 'AMOLED & Flexible Display Intelligence Service'

Items	Now	Future	Issues
<b>Form Factor</b>	Out Folding	In Folding	Reliability
<b>Bending Radius</b>	3~5mm	1mm	Total Thickness
<b>Hard coating</b>	Normal	Hybrimer	Low Hardness
<b>Cover Lens</b>	Ultra Thin Glass	Colorless PI	Whiten / Transform
<b>Polarizer</b>	Film Type	Coating Type	Low Optical
<b>Touch Sensor</b>	On TFE	In-Cell	Complex Structure
<b>Encapsulation</b>	1.5 dyads TFE	ALD TFE	Slow Process
<b>Display</b>	RGB OLED	RGB OLED	-
<b>TFT</b>	LTPS	OTFT LTPO	Low mobility
<b>Substrate</b>	Polyimide	Thinner Polyimide	Gas Barrier

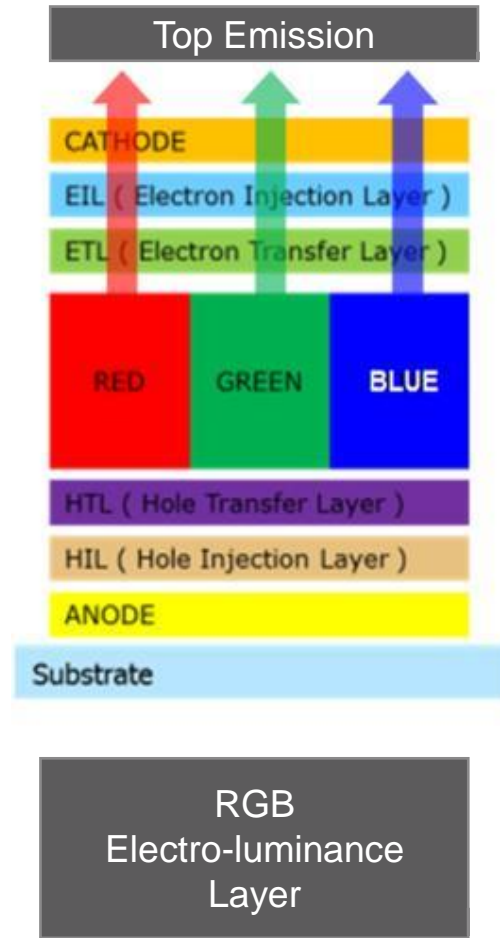
# OLED TV

LG Display White OLED TV Panel Shipment RGB vs, White OLED Structure

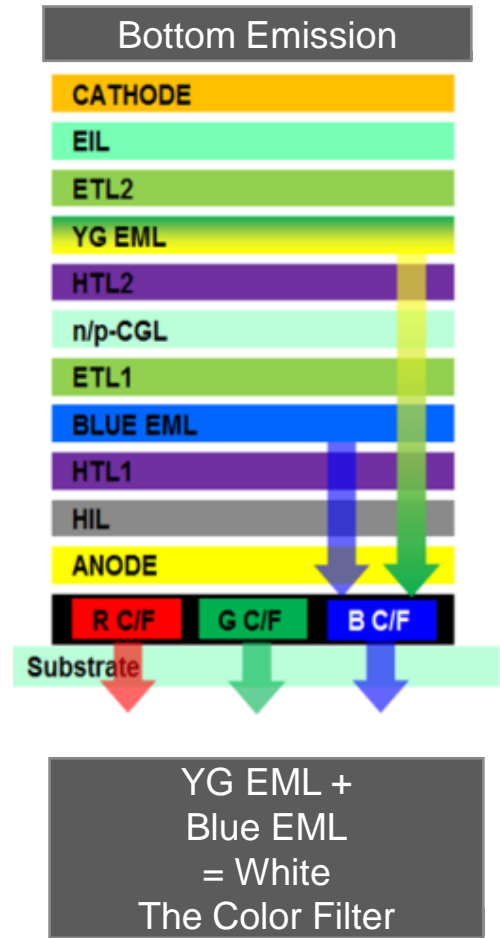


Source: IHS Markit

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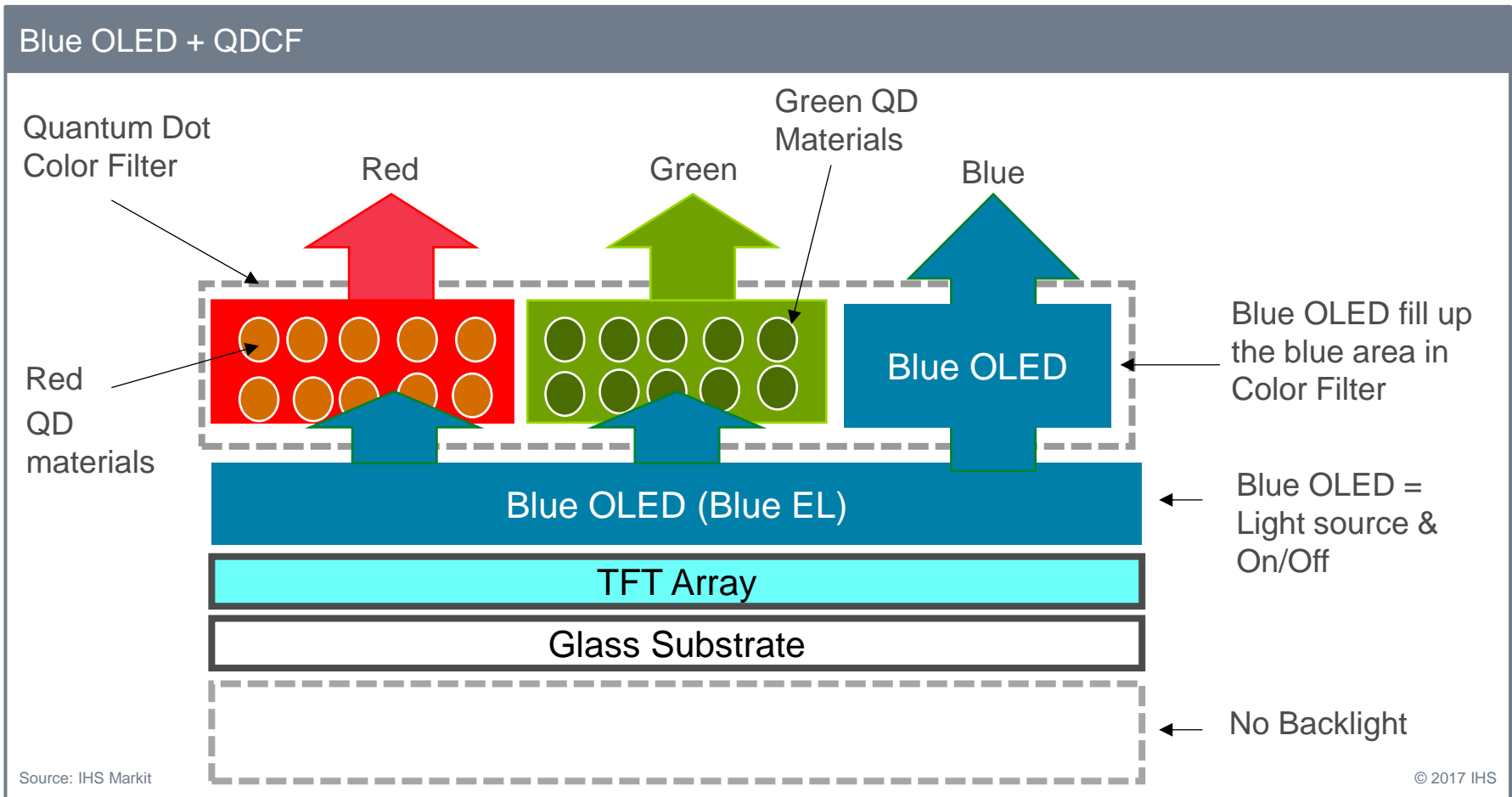
Source: IHS Markit



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# New – Blue OLED + QDCF (Quantum Dot CF)

- No liquid crystal, no backlight, no polarizer or other optical film. Combine the quantum dot and the OLED as a self-emissive display. In theory, possible better performance and lower cost than current OLED TV.



## 4. Display Supply Chain

## LCD TV panel allocations: 2018

Panel maker allocation plans for LCD TV brands for 2018, Q4 2017 Update (Million Units)											
	Samsung Display	LG Display	Innolux	AUO	Sharp	BOE	China Star	HKC Display	CHOT	CEC-Panda	Total
Samsung	17.5	0.7	7.7	8.3		8.0	5.8	0.4		0.2	48.6
LG		17.0	4.0	0.4	1.0	7.5	0.5	0.2			30.6
Sony	3.3	3.5	0.1	0.7		3.5	0.2				11.3
Toshiba		0.2	0.4								0.6
Sharp/Foxconn			6.5		6.9						13.4
Panasonic		2.8	2.8								5.6
Funai		1.5	2.2			0.5					4.2
TCL	2.9	1.7	1.1	1.5			16.5				23.7
Hisense	1.3	1.9	1.2	6.2		3.0	5.0	0.1		0.4	19.1
Skyworth		6.5	3.5			2.8	3.3	0.1		0.4	16.6
Haier	0.7	0.2									0.9
Changhong	0.6	1.3	0.7	2.9		1.9	2.1	0.1		0.3	9.8
Konka	2.5	1.9	0.3			3.3	0.2	0.1		0.4	8.7
OEM - TPV	1.4	3.7	0.3	3.5		4.2	0.3	1.5	1.5	1.4	17.8
Vestel	3.0	3.5	0.8	1.6		1.0	0.6				10.5
Others (incl. OEM)	5.5	3.7	14.0	1.4	0.0	9.3	3.5	6.2	1.0	4.9	49.5
<b>Total</b>	<b>38.7</b>	<b>50.2</b>	<b>45.6</b>	<b>26.7</b>	<b>7.9</b>	<b>45.0</b>	<b>38.0</b>	<b>8.5</b>	<b>2.5</b>	<b>8.0</b>	<b>271.1</b>

Notes: The simulated panel allocation plans for 2018 are based on the demand forecast of TV brands and the plans of panel makers. Panel allocation plans are subject to change based on changes to business plans and price negotiations.

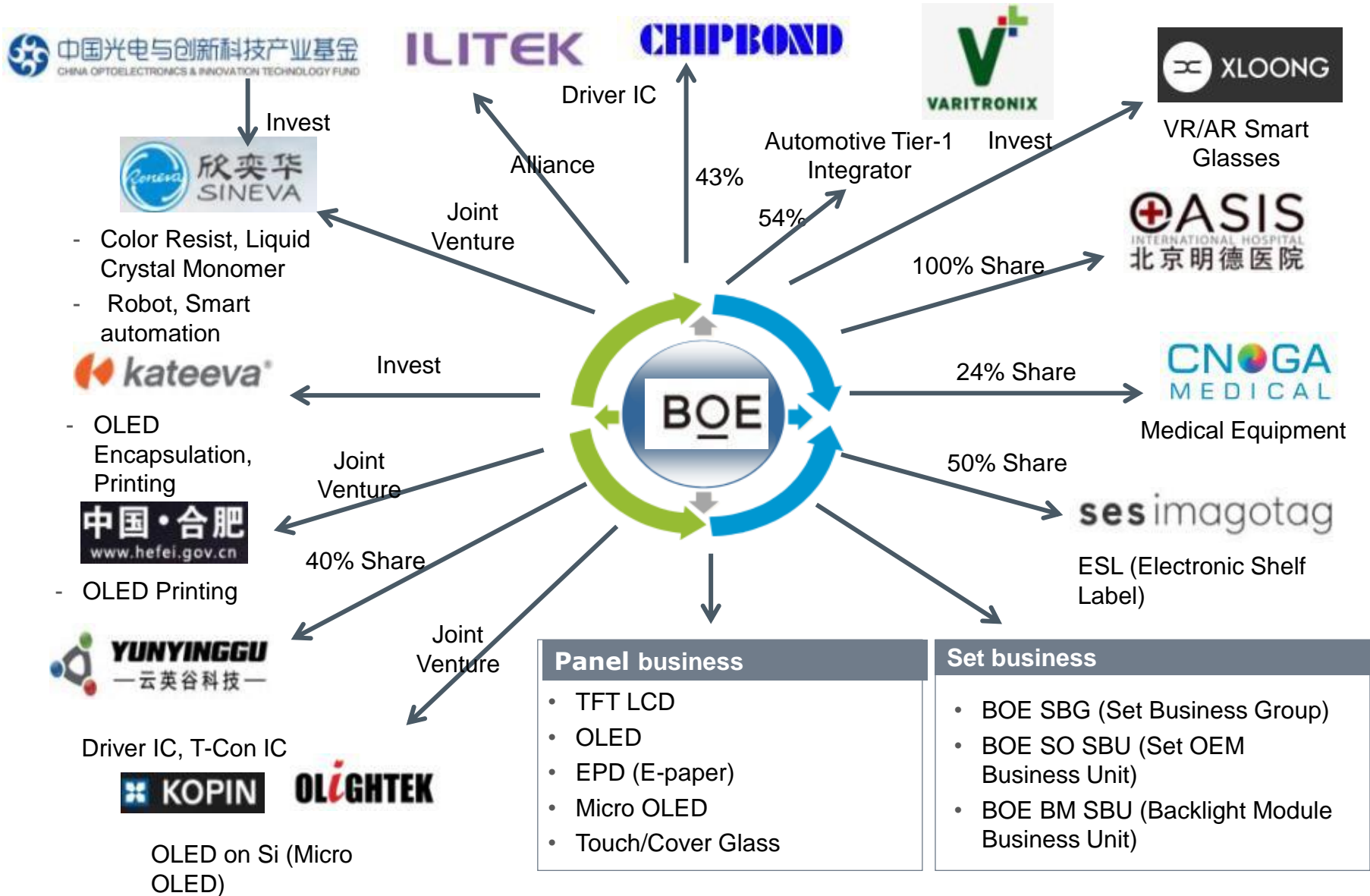
Due to concerns about panel supply constraints in 2018, brands added some volume to forecasts for negotiations.



## 8K LCD TV Panel Roadmap (a-Si vs. Oxide/60Hz vs. 120Hz)

Panel Makers	Samsung Display	LG Display	AUO	Innolux	Sharp	BOE	CSOT	CEC-Panda
60"					Oxide 120Hz 2018~			
65"	a-Si 120Hz 2019~	Oxide 120Hz 2019~	a-Si 60Hz 2018~	a-Si 60Hz 2017~	Oxide 120Hz 2020~	Oxide 120Hz 2019~	a-Si 120Hz 2020~	
68"								Oxide 120Hz 2018~
70"					Oxide 60Hz 2017~			
75"	a-Si 120Hz 2019	Oxide 120Hz 2019~	Oxide 120Hz 2019~	a-Si 60Hz 2018~	Oxide 120Hz 2020~	Oxide 120Hz 2018~	a-Si 60Hz 2020~	
77"		a-Si 120Hz 2018~						
82"						a-Si 60Hz 2016~		Oxide 120Hz 2018~
85"			a-Si 120Hz 2018~	a-Si 120Hz 2018~			Oxide 120Hz 2018~	
88"		a-Si 120Hz 2019~						
98"	a-Si 120Hz 2016~	a-S 120Hz 2017~				a-Si 60Hz 2015~		Oxide 120Hz 2017~
110"						a-Si 120Hz 2017~		
130"							a-Si 120Hz 2020~	

# BOE Vertical integration



## Notebook Panel Supply Chain - 2018

Notebook PC panel allocations – 2018 (in millions)

Brand	AUO	BOE	CEC-Panda	Hannstar	IVO	Innolux	Japan Display	LG Display	Panasonic	Samsung	Sharp	Grand Total
Acer	5.4	2.8	0.5			4.1		0.6				13.4
Apple		2.0						12.5			1.8	16.3
Asus	5.0	4.9	0.2			4.1		0.8				15.0
HP	13.5	12.5	0.3		0.6	11.6		3.5			0.1	42.1
Dell	6.8	8.5	0.7		0.5	5.2	0.1	3.5			2.2	27.5
Lenovo	8.3	10.2	0.2		1.2	9.0		4.3	0.1		0.2	33.4
Microsoft								2.6				2.6
Samsung	0.8	1.0	0.2			0.2					0.4	2.6
Toshiba						0.3		0.6			0.1	1.0
Others	2.2	10.1	3.9	1.0	3.7	6.5	0.1	4.6	0.1		1.0	29.8
Grand Total	42.0	52.0	6.0	1.0	6.0	41.0	0.2	33.0	0.2	0.0	5.8	183.8

Notes: The business plan figures are not official company data. This is derived from IHS supply chain checks. These numbers are subject to change from time-to-time, given the complexity and dynamics in the market.

# Tablet Panel Supply Chain - 2018

Tablet PC panel allocations – 2018 (in millions)													
Brand	AUO	BOE	CPT	Hannstar	IVO	Innolux	Japan Display	LG Display	Panasonic	Samsung	Sharp	Tianma	Grand Total
Acer	0.1												0.1
Amazon	3.6	2.0	4.5	0.4		6.0							16.5
Apple		6.0						25.0			15.0		46.0
Asus	0.5	0.5										0.2	1.2
HP	0.3												0.3
Huawei	0.4	8.4	0.4			5.2	0.1					2.0	16.5
Dell													0.0
Lenovo	0.6	5.0				2.0							7.6
Microsoft									0.2		0.4		0.6
Samsung		16.0	0.8							3.6			20.4
LGE		0.4				0.8							1.2
Others	16.5	31.7	29.3	14.6	5.5	11.0	0.1	0.0	0.2	0.6	1.0	0.8	111.3
Grand Total	22.0	70.0	35.0	15.0	5.5	25.0	0.2	25.0	0.4	4.2	16.4	3.0	221.7

Notes: The business plan figures are not official company data. This is derived from IHS supply chain checks. These numbers are subject to change from time-to-time, given the complexity and dynamics in the market.

# Monitor Panel Supply Chain – 2018

Desktop Monitor and All-in-one PC panel allocations – 2018 (in millions)

Panel	Acer	Apple	Asus	BenQ	Dell	HP	Lenovo	LGE	Samsung	TPV	Viewsonic	Others	Total 2018
AUO	3.3		1.5	2.9	4.2	1.6	2.6	1.3	1.6	2.7	0.1	4.2	26.0
BOE	0.6		0.3		9.1	6.0	3.7	2.1	3.6	3.8		6.8	36.0
CEC-Panda					0.9			0.9		0.9		3.2	6.0
HannStar												0.0	0.0
InfoVision											0.1	0.1	0.3
Innolux	1.9		1.8		3.5	0.9	3.6	0.4	1.5	4.2	1.6	4.6	24.0
LG Display	1.1	2.5	1.3	0.3	8.0	6.8	4.0	5.0		4.3		1.4	34.7
Panasonic												0.3	0.3
Samsung					2.5	4.0	2.1		3.5	0.9		2.0	15.0
Sharp												0.3	0.3
Tianma													
Total 2018	6.9	2.5	5.0	3.2	28.2	19.3	16.0	9.7	10.2	16.7	1.9	24.3	143.9

Notes: The business plan figures are not official company data. This is derived from IHS supply chain checks. These numbers are subject to change from time-to-time, given the complexity and dynamics in the market.

Source: IHS

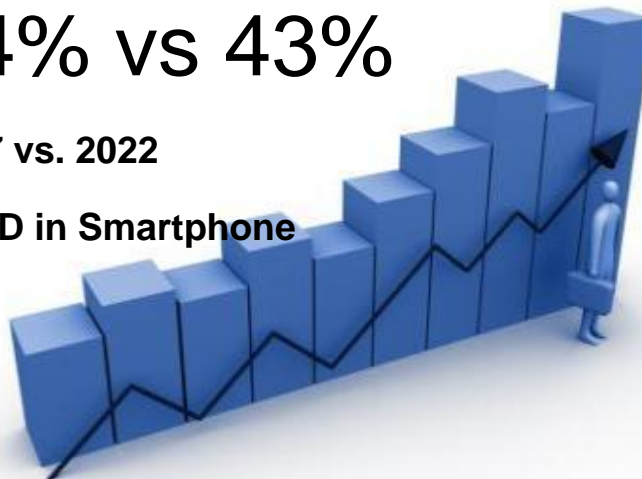
# 5. Conclusion

# Key Takeaways

24% vs 43%

2017 vs. 2022

OLED in Smartphone



- 16:9
- 18:9
- 18.5:9
- 19.5:9
- Full Screen Notch

## Gen10.5

- Each Fab = 7M of 65"
- Over-supply pressure to Gen6 and Gen8
- Many new process technology
- 65" CashCost Below \$300

 **20** fabs of Gen5.5/6 a-Si/LTPS/OLED in China by 2022

 **19** fabs of Gen8/Gen10.5 in China by 2022



## Question Mark



The Foldable OLED/Rollable OLED is not only a technical issue but also consumer behavior issue, what are the new applications of OLED?



Over-supply, panel price fall by 20%-30%, inventory adjustment, Smartphone OLED is in over-supply



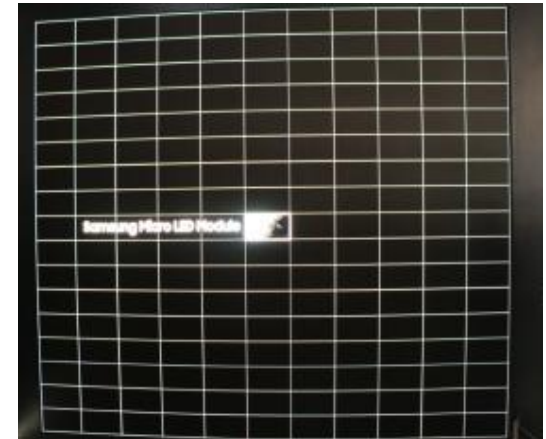
# Special Appendix – New Displays Show in CES 2018



## Samsung 146" Micro LED Display – “the Wall”

- Prototype. 146" 4K = 30 PPI (Pixel Per Inch) = Pixel pitch 0.8417mm (847 um), Subpixel pitch = 0.28mm
- Consist in 11x17 (= 187) pieces of LED module tile.

### Samsung 146" Micro LED Display in CES 2018



# LG Display Rollable 65" UHD OLED TV

## LG Display Rollable 65" UHD OLED TV



- LG Display claimed 100K times bending durability and the radius is 50R.
- It can be rolled up and hidden when not in use, and the small size of the rolled-up screen means that it can be more easily moved and stored, allowing for better space utilization

# Innolux “Active Matrix Mini LED “ Automotive Display

## Innolux LCD Panel With Mini LED Backlight for Automotive Display



- LTPS LCD with Mini LED Backlight
- The AM means the local dimming is controlled by each LED not like traditional by each zone
- AM mini LED automotive panel offers OLED-level contrast ratio and comparable sharpness without the drawbacks of limited temperature range, short lifetime and ghost image. The brightness could be multiple times OLED's with the help of accurate electric current calibration,

## Byton 49" Full screen automotive display

- Display supported by BOE. Accordingly it is a revision of the industrial/public display panel. The vertical height of the display is 10", and the horizontal length of the display is 49".

### Byton 49" full screen automotive display



# Samsung Harmon

- Samsung Harmon show the digital cockpit. The displays are including QLED display, and transparent flexible OLED, and round OLED. Harman's concept dashboard is a hot mess of OLED and QLED screens, offering up all sorts of information to the driver. The goal with this concept was to use the power of flexible screens and connectivity to create an experience much more helpful to the average driver. An OLED down the center console doesn't even look like a screen, yet it shows touch controls that the driver can change. The "moonroof" is a transparent QLED panel on the roof of the car, as the display scenery.

## Samsung Harmon Digital Cockpit



Transparent OLED

Source: IHS



digital cockpit.



Moon Roof



Flexible OLED

# ZTE smartphones

- ZTE showed its dual-screen smartphone AXON at CES 2018, with a two 5.2-inch FHD screen and 426 PPI. ZTE calls it foldable smartphone. However, the design looks like two smartphones hinged together with foldable hinge.

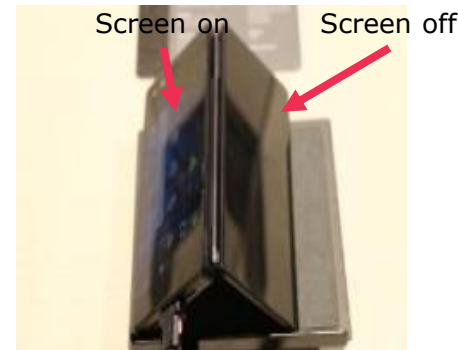
## ZTE's dual-screen smartphones



Dual mode-front



Dual mode-back



Mirror mode



- Size: two 5.2-inch (1920×1080) PPI 426 Gorilla Glass G5
- OS/platform: Android 7.1.2
- Battery: 3180mAh
- Memory: 4GB RAM+64GB ROM
- Bluetooth: 4.2
- Wi-Fi: On
- Camera: 20MP
- Sound:
  - Headphone jack (3.5mm)
  - High-fidelity sound with Dolby Atmos
  - Dual speakers

Source: ZTE - photo taken by Nick Jiang/IHS Markit at CES, Las Vegas, NV, January 2018

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