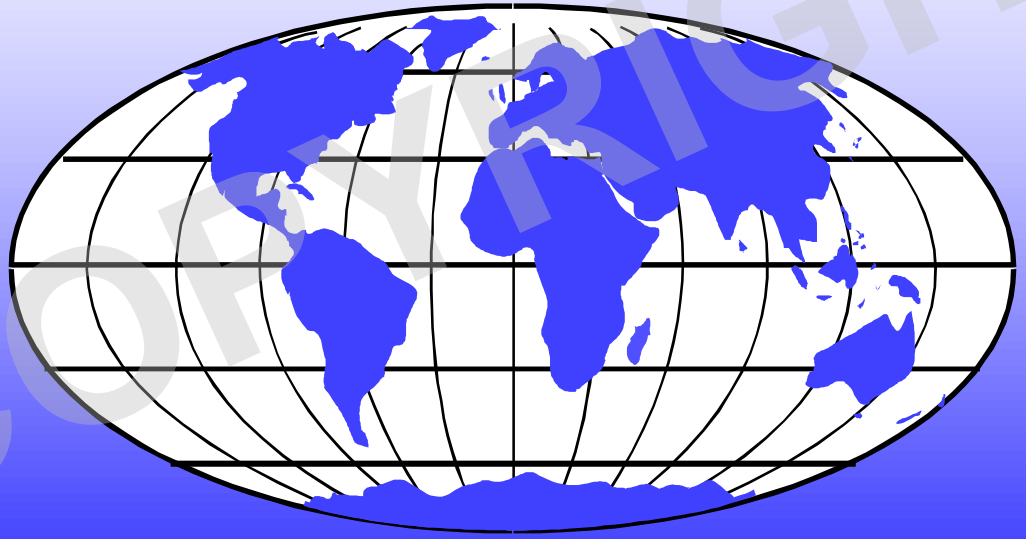
FINFET AND FD SOI: MARKET AND COST ANALYSIS

SEPTEMBER 18, 2018



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INTERNATIONAL BUSINESS STRATEGIES BACKGROUND

- In business for 30 years
- Interface with most global leaders in electronics industry, with customers in U.S., Europe, South Korea, Japan, Taiwan, China, India, etc
- Interface with and support major global corporations such as Intel, Qualcomm, Broadcom, Microsoft, Nokia, Samsung, SK Hynix, Sony, Toshiba, Apple, Cisco, Huawei, IBM, Fujitsu, Canon, NEC, Hitachi, Renesas, TSMC, STMicroelectronics, TI, ARM, Cadence, Synopsys, Mentor Graphics, Seagate, Globalfoundries, SMIC, NXP Semiconductors, and others
- Interface with and support financial institutions such as Goldman Sachs, Carlyle, Blackstone, CitiGroup, Warburg Pincus, Walden, KKR, Morgan Stanley, Credit Suisse, BNP Paribas, Bain Capital, Bank of America, TPG, and others
- Strong expertise in China

  Published two books on China: *China's Globalization* (*How China Becomes No. 1*) and *Chinamerica* (McGraw Hill) and contributed to Wall Street Journal, Economist, New York Times, Forbes blogs, China Daily, Global Times, EE Times, Xinhua, etc
- Support of strategic initiatives for number of global technology leaders

IBS HAS HIGH MARKET SHARE ON TECHNOLOGY AND STRATEGY BUSINESS

KEY ISSUES IN SEMICONDUCTOR INDUSTRY

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- AI will be key driver for growth of semiconductor industry over next decade
- AI capabilities will transform many industries
  - Autonomous driving and autonomous transportation
  - Image enhancement for three-image-sensor-based smartphones
  - AR capabilities for smartphones, including support for ToF
  - Search engines in data centers
  - VR platforms for gaming and other applications
- Smartphones are largest consumer of semiconductor products
  - Smartphone volume is declining in 2018, but semiconductor content per phone is increasing
  - Largest smartphone vendors by unit volume in 2018 are Samsung, Huawei, and Apple followed by Xiaomi, OPPO, and Vivo

    (Four Chinese vendors are in top six global smartphone vendors)

KEY ISSUES IN SEMICONDUCTOR INDUSTRY (CONTINUED)

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- Autonomous driving is building momentum
  - While Tesla is technology leader, largest market for autonomous driving in 2020 to 2027 will be China
  - Growth of ADAS infrastructure in China is supported by 5G
  - China is 12 to 18 months ahead of others in 5G technology

    Will have three million to four million 5G base stations in 2020 to 2021
- Electrification of vehicles is in high growth, with strong demand for silicon IGBT products

  SiC and GaN will be high growth, which will provide opportunities for substrates and foundry support
- Fan-out wafer-level packaging technology is also in high growth, with role of foundry vendors increasing in support of packaging

  OSATs will continue to grow and increase participation in high-density fan-out

SEMICONDUCTOR INDUSTRY CONTINUES TO HAVE HIGH LEVELS OF INNOVATION

WAFER SUPPLY

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- Three major technologies will dominate IC supply, including:
  - ***FinFET:*** Digital emphasis
  - ***HKMG bulk CMOS:*** Probable limit at 22nm
  - ***FD SOI:*** Limits at 12nm or potentially 10nm
- 7nm FinFET will be in high volume in Q4/2018 and is projected to represent 25% of TSMC's revenues in Q4/2018
  - 10nm represented 25% of TSMC's revenues ($2339 million) in Q4/2017 and 13% ($996 million) in Q2/2018
  - 5nm is scheduled for high-volume production in H2/2020
  - Samsung has similar schedule to TSMC and is potentially ahead of TSMC in process technology
  - FinFETs are highly effective for digital designs but marginal for RF and analog-centric mixed-signal designs

WAFER SUPPLY (CONTINUED)

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- HKMG bulk CMOS is in high-volume production
  - 28/22nm revenues will be $11.5 billion in 2018
  - Bulk CMOS is also used for >28nm, where revenues will be $32.9 billion in 2018
  - Key limitation of bulk CMOS is difficulty with scaling below 22nm

    (Some volume production in past was at 20nm)
- FD SOI transistor cost can be lower than bulk CMOS and FinFET because of fewer mask steps
  - FD SOI has very low active and standby power consumption with use of back biasing
  - RF capabilities of FD SOI are superior to bulk CMOS and are much better than FinFET

SEMICONDUCTOR INDUSTRY SHOULD PLAN TO HAVE THREE MAINSTREAM PROCESS TECHNOLOGIES IN FUTURE

TRANSISTOR DENSITY

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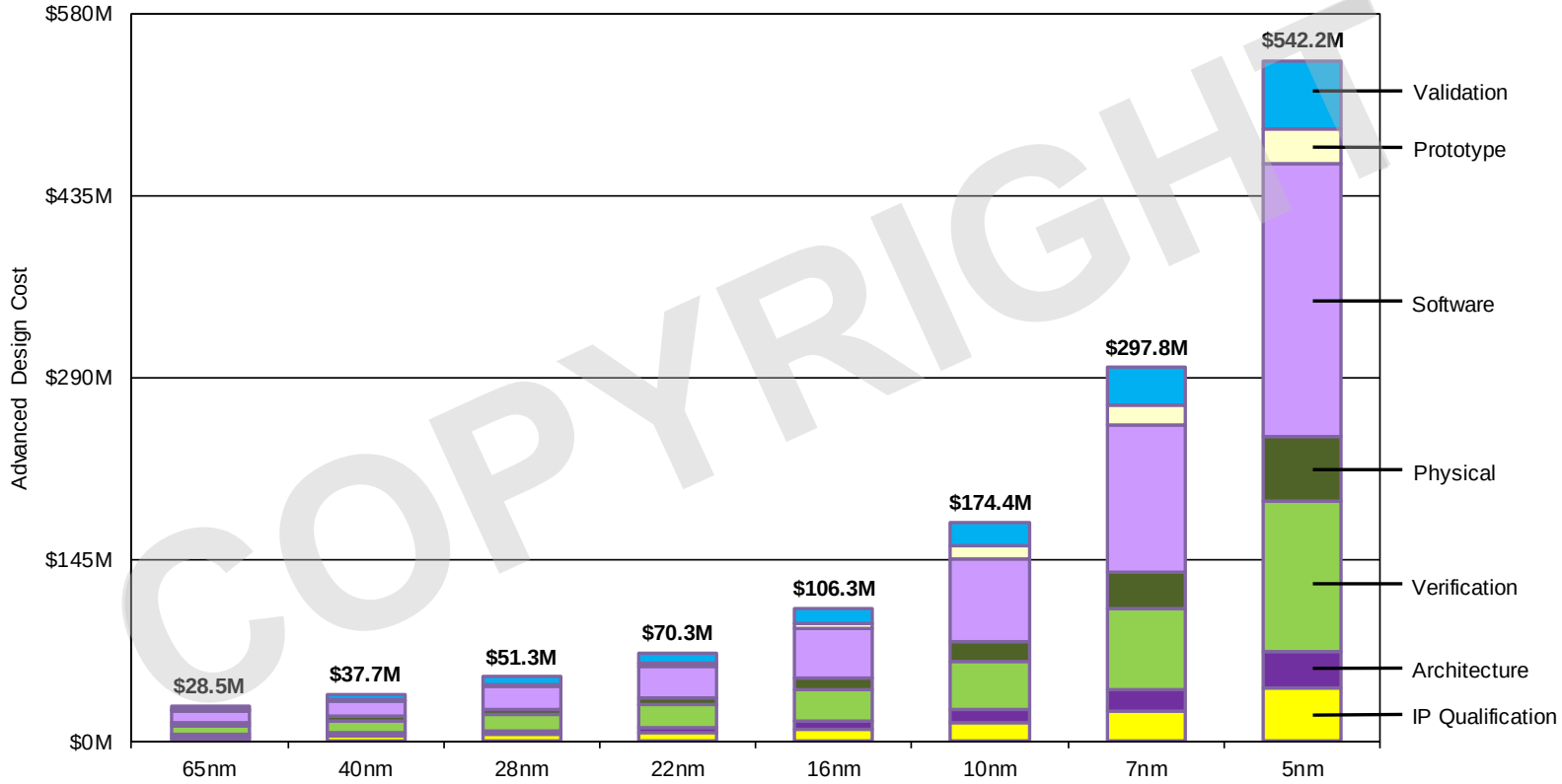
	16nm	12nm	10nm	7nm	7nm Plus	5nm	3nm
Transistor density (M/mm²)	**26.4**	**31.7**	**49.0**	**87.1**	**104.5**	**156.8**	**196.0**
Transistor count (MU)							
20mm²	528	634	980	1,742	2,090	3,136	3,920
40mm²	1,056	1,268	1,960	3,484	4,180	6,272	7,840
60mm²	1,584	1,902	2,940	5,226	6,270	9,408	11,760
80mm²	2,112	2,536	3,920	6,968	8,360	12,544	15,680
100mm²	2,640	3,170	4,900	8,710	10,450	15,680	19,600
200mm²	5,280	6,340	9,800	17,420	20,900	31,360	39,200

CHIP (100mm² WITH 7nm PLUS) WITH 10.5 BILLION TRANSISTORS MAY COST $500 MILLION TO DESIGN

ADVANCED DESIGN COSTS



LIMITS NUMBER OF PARTICIPANTS IN ADVANCED TECHNOLOGIES

LIFETIME OF WAFER FABS

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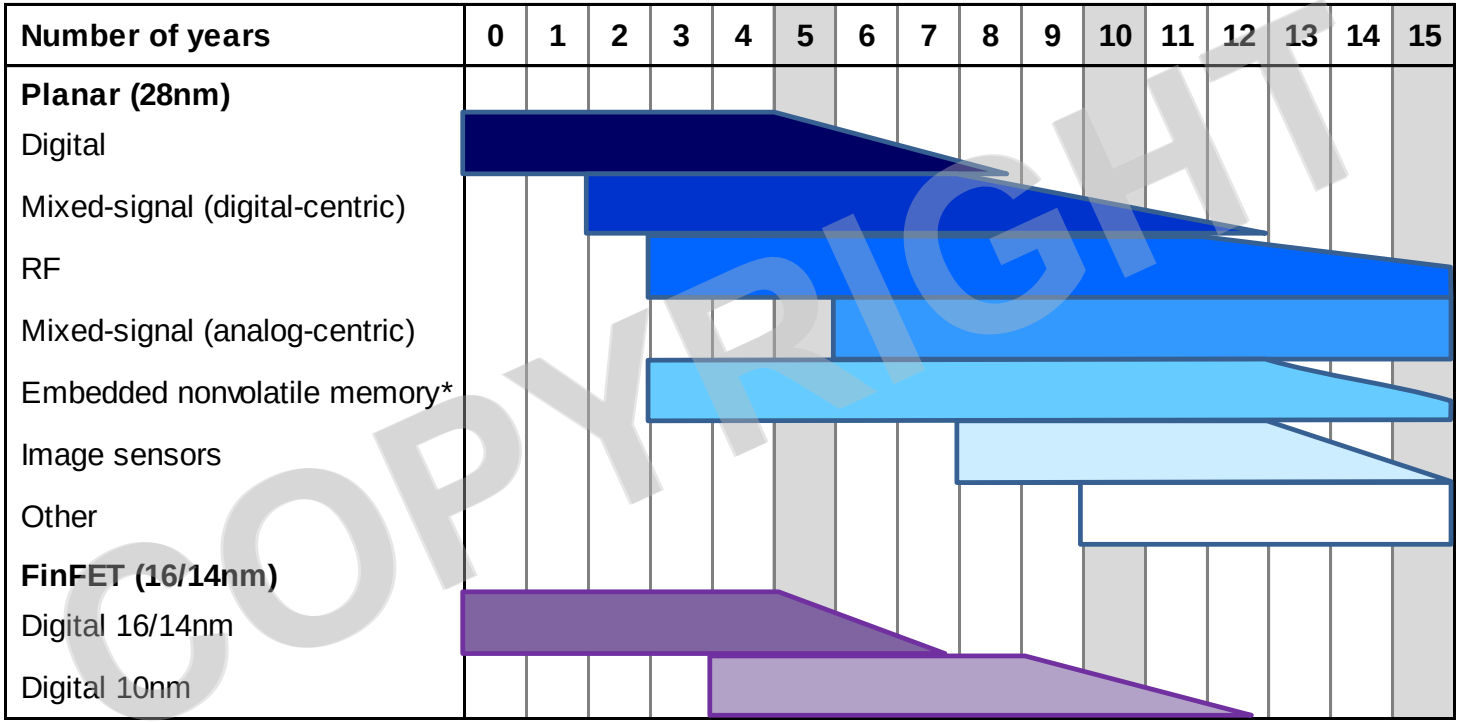

Note:

* Includes automotive.

FINFETS WILL CONTINUE TO HAVE STRONG DEMAND FOR DIGITAL DESIGNS

TSMC'S REVENUES BY FEATURE DIMENSION (FY)

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	2016									2017 (Dec 31, 2017)									2018				
($M)	Q1	%	Q2	%	Q3	%	Q4	%	TOTAL	Q1	%	Q2	%	Q3	%	Q4	%	TOTAL	Q1	%	Q2	%	TOTAL
10nm	--	--	--	--	--	--	--	--	--	--	--	72	1	850	10	2,339	25	3,261	1,548	19	996	13	2,544
20/16nm	1,449	23	1,580	23	2,500	31	2,680	33	8,209	2,444	31	1,874	26	2,040	24	1,871	20	8,230	1,792	22	1,915	25	3,707
28nm	1,891	30	1,923	28	1,935	24	1,949	24	7,698	1,971	25	1,947	27	1,955	23	1,684	18	7,557	1,629	20	1,762	23	3,391
45/40nm	882	14	1,030	15	1,048	13	974	12	3,935	1,025	13	937	13	1,020	12	936	10	3,918	896	11	843	11	1,739
65nm	630	10	824	12	887	11	893	11	3,235	867	11	721	10	850	10	842	9	3,280	733	9	689	9	1,423
90nm	378	6	343	5	403	5	406	5	1,531	315	4	360	5	425	5	374	4	1,475	407	5	383	5	790
0.13/0.11µm	126	2	137	2	242	3	162	2	668	158	2	216	3	255	3	187	2	816	163	2	153	2	316
0.18/0.15µm	693	11	756	11	726	9	812	10	2,987	867	11	793	11	850	10	842	9	3,352	733	9	689	9	1,423
≥0.25µm	252	4	275	4	323	4	244	3	1,093	237	3	288	4	255	3	281	3	1,061	244	3	230	3	474
TOTAL	6,302	100	6,869	100	8,064	100	8,120	100	29,355	7,885	100	7,209	100	8,499	100	9,357	100	32,951	8,146	100	7,660	100	15,806

7nm WILL REPRESENT 25% OF TOTAL REVENUES IN Q4/2018, WHICH WILL BE APPROXIMATELY $2.8 BILLION

PERSPECTIVE ON GATE COSTS

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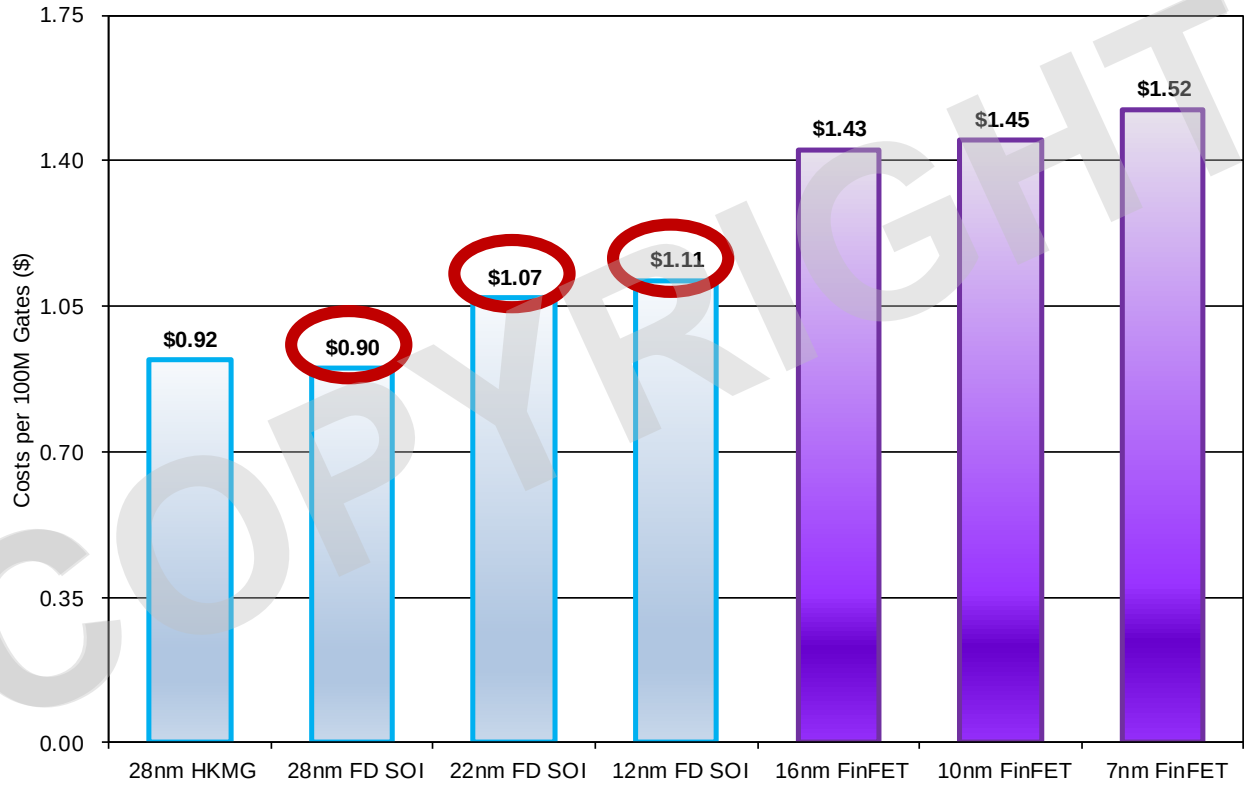

FD SOI IS COST COMPETITIVE

COST BENEFITS OF FD SOI

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- Gate cost of 22nm FD SOI is comparable to 28nm HKMG bulk CMOS (depends on depreciation level)
- ***12nm FD SOI will have lower gate cost than FinFETs***

  22.4% lower than 16nm FinFET, 23.4% lower than 10nm FinFET, and 27.0% lower than 7nm FinFET

  Key reason for lower gate cost of 12nm FD SOI is fewer number of mask steps, which compensates for higher substrate costs
- Present focus of FD SOI is on 28/22nm, but with roadmaps to 18nm and 12nm

FINFETS WILL CONTINUE TO EXPERIENCE GROWTH, WITH TSMC AND SAMSUNG AS FOUNDRY VENDORS FOR ≤10nm

INTEL WILL BE POTENTIAL CANDIDATE IN FUTURE

IMAGE SENSOR MARKET

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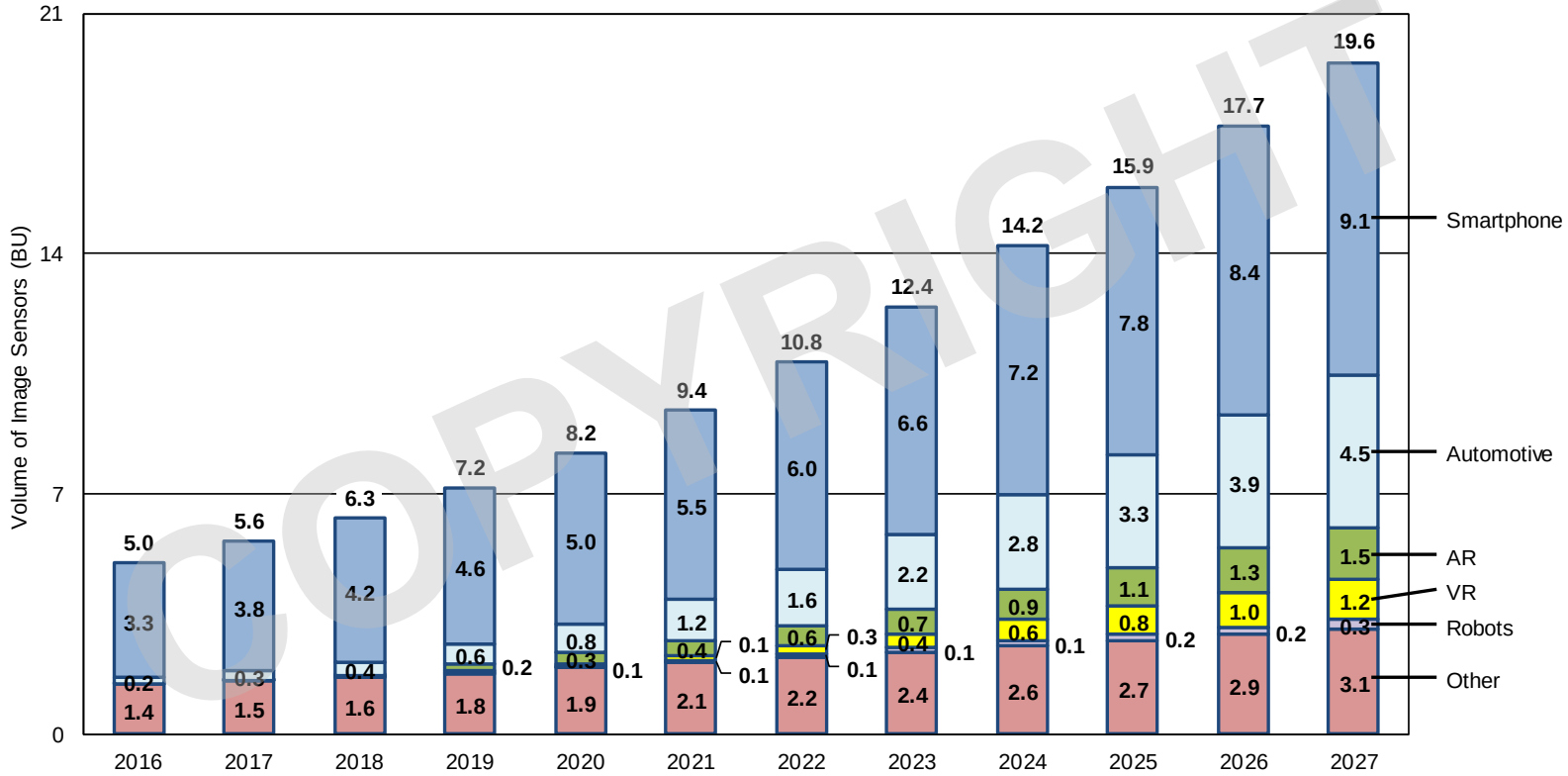

ISP IS ONE POTENTIAL GROWTH MARKET FOR FD SOI

ISP WAFER REQUIREMENTS

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- Volume will be 19.6 billion units in 2027

  With 30mm² chip size and 1950 good dies per wafer, will require 10.1 million wafers (842,000 WPM)

- Each image sensor will require ISP, which is bonded directly to image sensor

  ISP will also require 842,000 WPM in 2027

- FD SOI may provide better analog functionality (ADC), lower noise, and lower power consumption compared to 22nm HKMG bulk CMOS and 16nm FinFETs

  FD SOI may also give cost-competitive unit area with 22nm bulk CMOS due to fewer mask steps

  Cost per unit area of FinFET is too high at ≤16nm for ISP support

- ISP functionality will need to be optimized for specific applications such as automotive, security, and AR-based smartphones

  Result is that there will be many ISP products

EXAMPLE OF APPLICATION THAT MAY BENEFIT FROM FD SOI IS ISP

KEY FACTORS ARE 28nm, 22nm, OR 18nm AS WELL AS DIE COST

IOT SEMICONDUCTOR MARKET

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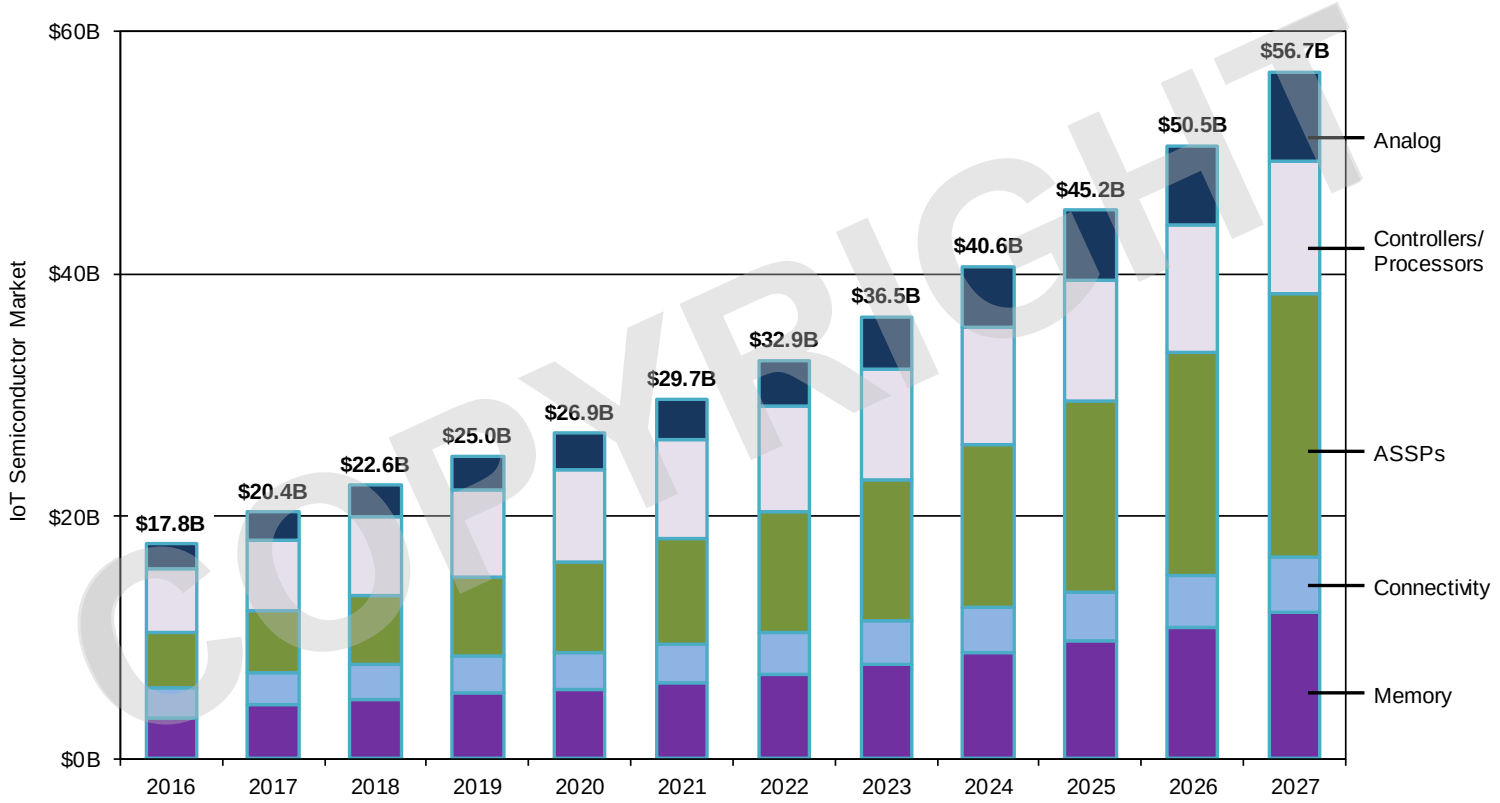

IOT MARKET HAS GOOD GROWTH POTENTIAL AND IS GOOD CANDIDATE FOR FD SOI

KEY ISSUES IN IOT SEMICONDUCTORS

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- IoT applications will experience strong growth because ***efficient connectivity to cloud*** is emerging

  LPWA (primarily NB-IoT) will be key connectivity in short term and 5G in longer term

- ***Approaches for monetizing data*** are being established by number of companies

  AI technology for ADAS and consumer health is building momentum

- Wearable health monitors also represent IoT devices that have high growth potential

  Will have sensors, ADC, processors, and NB-IoT

  Best technology option is FD SOI due to support of RF and low-noise analog functionality and low power

KEY ISSUES IN IOT SEMICONDUCTORS (CONTINUED)

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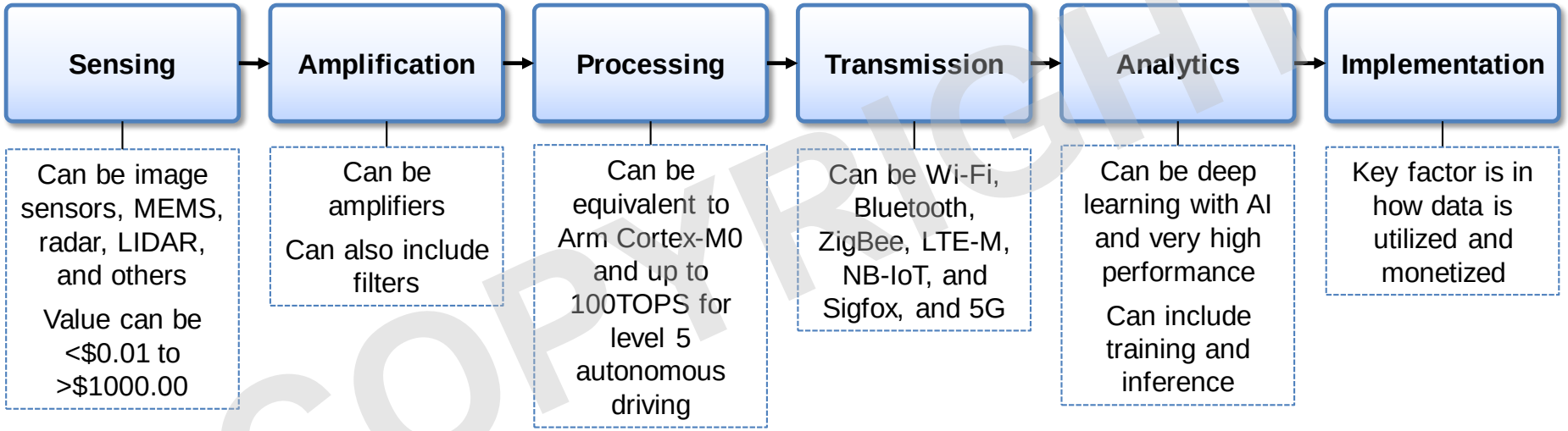
IOT BUILDING BLOCK FUNCTIONS



EDGE DEVICES, WHICH INCLUDE IOT, HAVE HIGH GROWTH POTENTIAL

FD SOI IS BEST TECHNOLOGY BECAUSE OF LOW POWER CONSUMPTION AND RF CONNECTIVITY

PERSPECTIVE ON CHINA

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- China is changing from being follower in many areas of technology to becoming leader
- China is leader in mobile 5G adoption and will have one billion 5G users in 2025 to 2028
- China will be volume leader in electric vehicles (40 million units in 2027 compared to one million units in 2017)

  Large battery capacity is being established to support electrification
- Autonomous driving is expected to increase rapidly in China, with Baidu being key driver
- Display capabilities are strengthening in China

  OLED technology of BOE is becoming competitive
- China is building wafer capacity for FinFETs (TSMC and SMIC) and bulk CMOS (SMIC, Huali, HHGrace, and CSMC)

  There is excess capacity in 28nm bulk CMOS in Q3/2018

IT IS IMPORTANT FOR CHINA TO ALSO BUILD LARGE WAFER FAB CAPACITY FOR FD SOI

NEAR-TERM SUPPLY COMES FROM GLOBALFOUNDRIES AND SAMSUNG

SEMICONDUCTOR CONSUMPTION PATTERN IN CHINA

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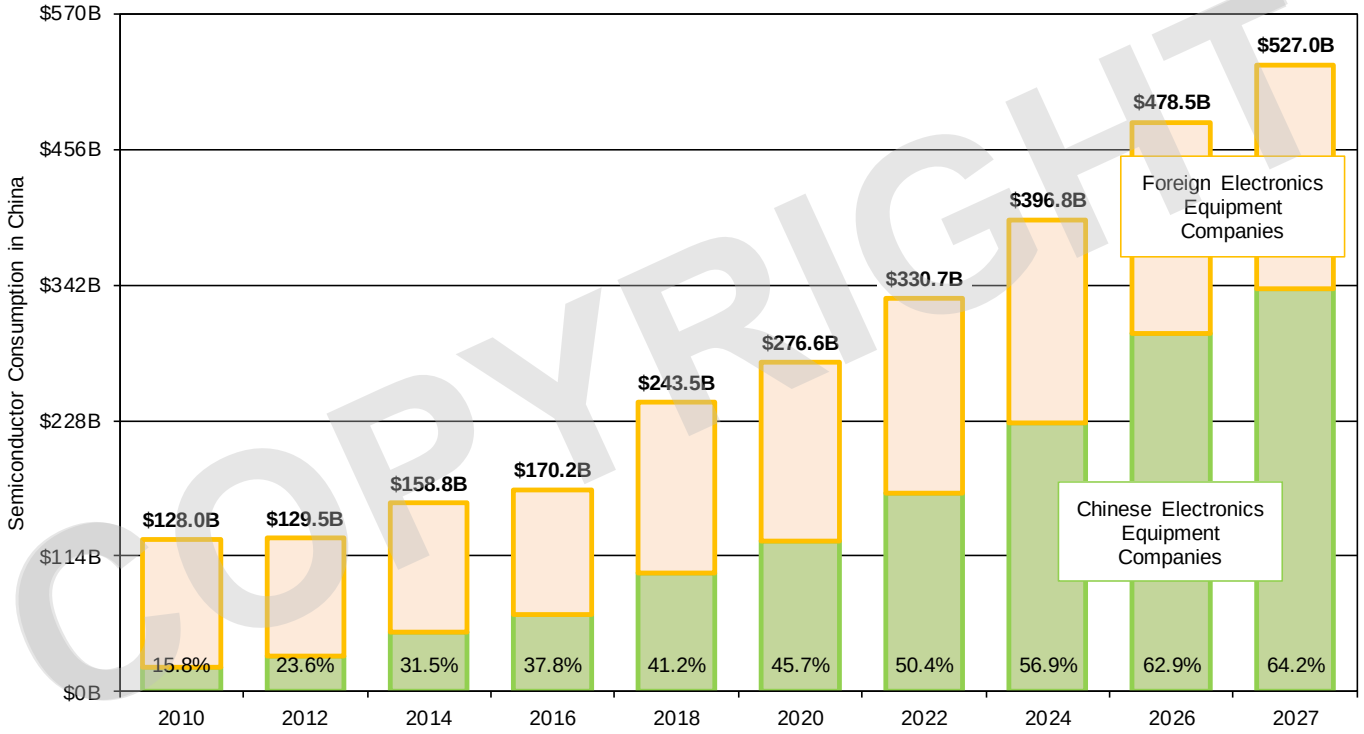

CHINESE COMPANIES CONSUMED 15.8% OF TOTAL SEMICONDUCTORS IN CHINA IN 2010 BUT WILL CONSUME 64.2% IN 2027

SEMICONDUCTOR SUPPLY IN CHINA

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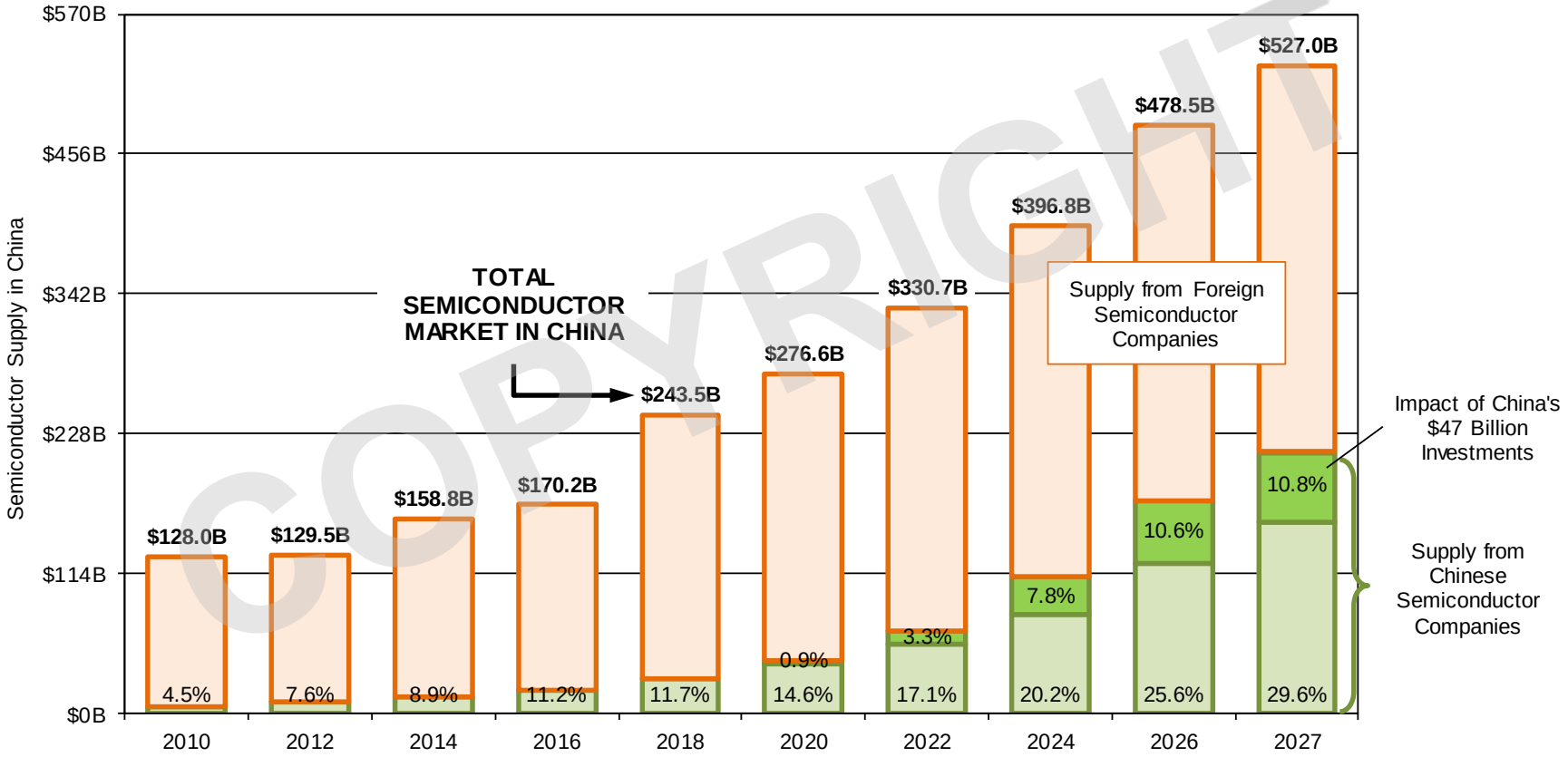

5G SMARTPHONE VOLUMES

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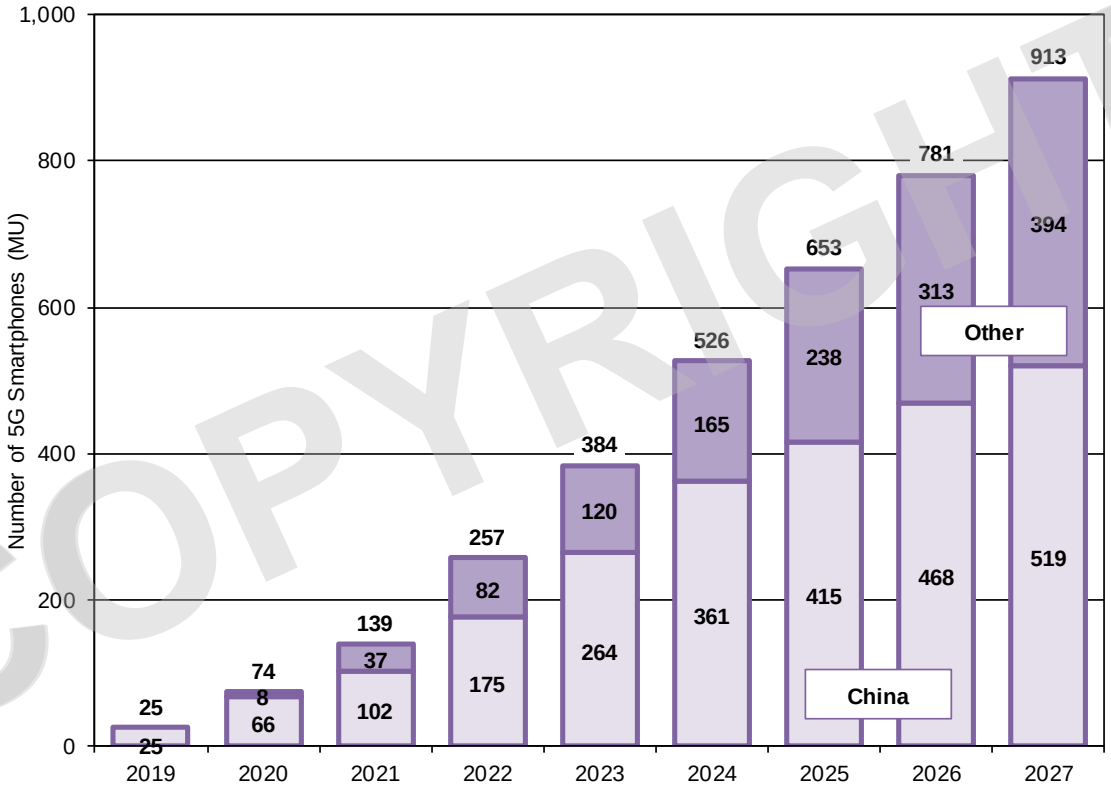

CHINA IS LEADER IN SMARTPHONE VOLUME AND 5G

CHINA ELECTRONICS INDUSTRY PRODUCTION

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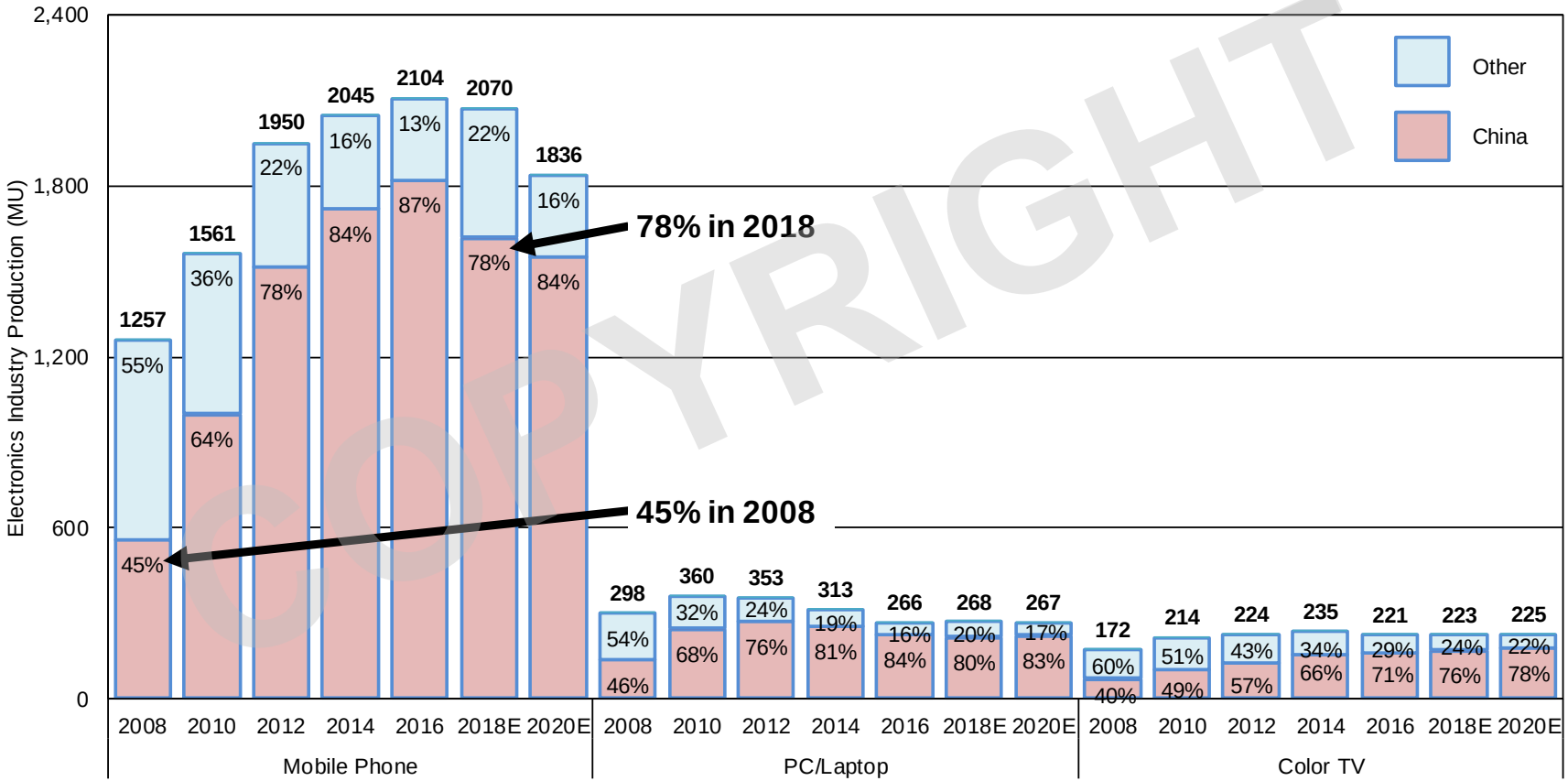

TAM FD SOI FOUNDRY

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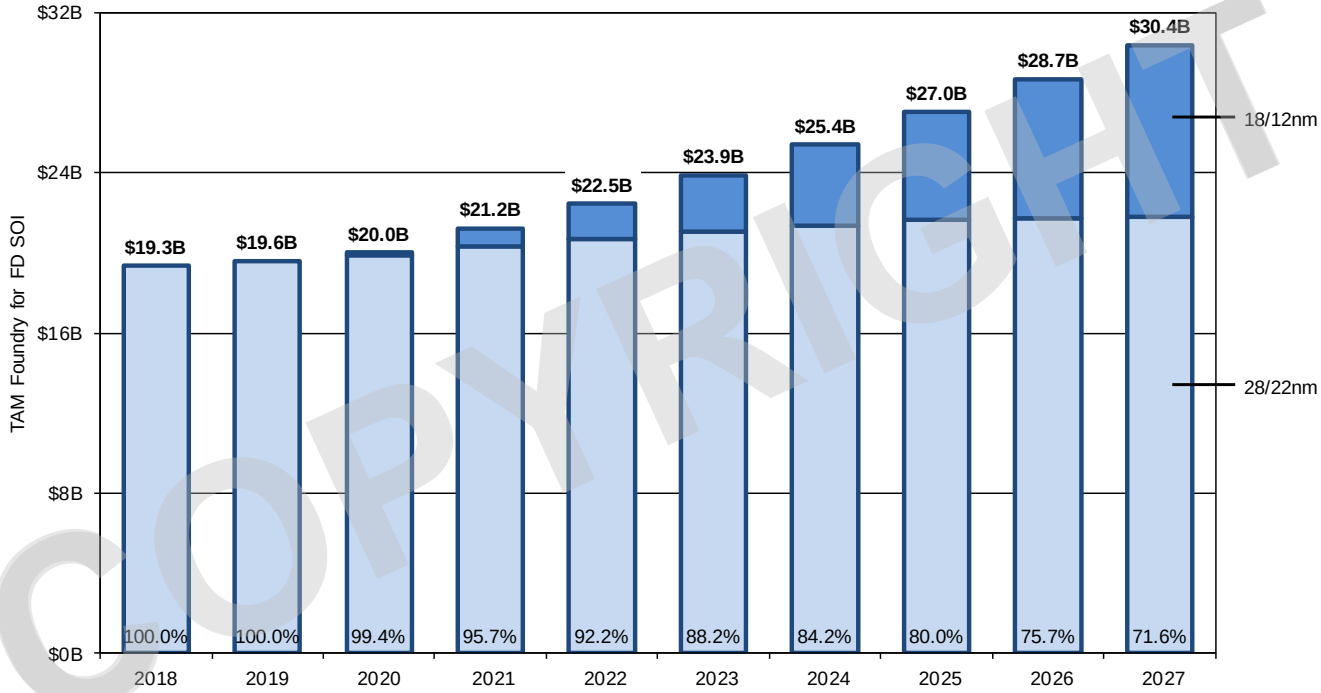

18/12nm TAM IS BASED ON ≤16nm FOUNDRY MARKET WHILE 28/22nm TAM IS BASED ON 28/22nm AND 45nm FOUNDRY MARKET

LARGE FOUNDRY TAM FOR FD SOI

TAM FD SOI PRODUCT VALUE

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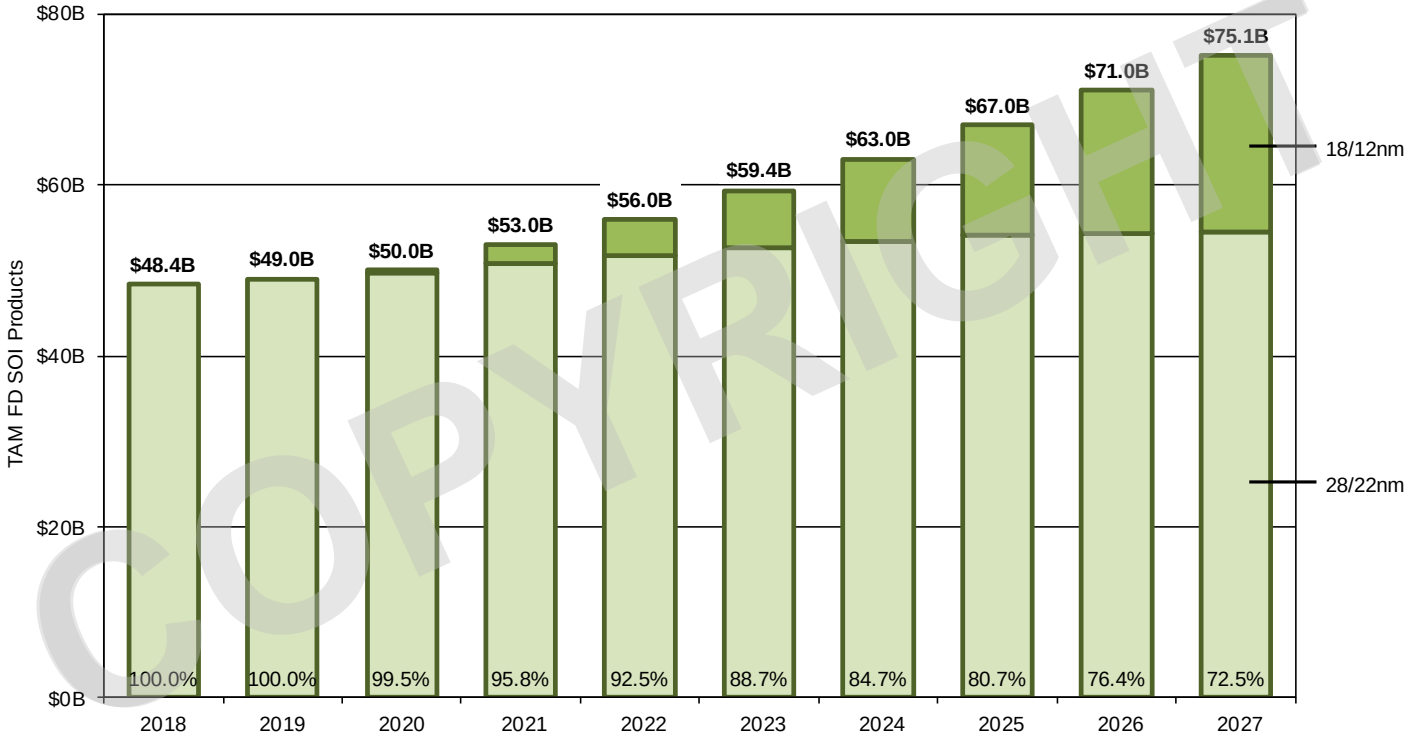

FD SOI PRODUCT VALUE IS BASED ON LOWER COST, LOWER POWER CONSUMPTION, AND COMPETITIVE PERFORMANCE

CONCLUSION

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- Semiconductor market is in growth mode, but there will be some volatility in 2020

  Smartphones are largest user of semiconductors

  Trade issues, however, could disrupt smartphone market

  AI is key long-term growth driver for smartphones and other applications

- China is leader in 5G, with installation of three million to four million base stations by 2020 or 2021

  Projection of one billion 5G users for 2025 to 2028

- Migration for digital designs to 7nm in 2018, 7nm Plus in 2019, and potentially 5nm in 2020

  TSMC and Samsung will likely be only foundry vendors at ≤7nm

- FD SOI, which includes 28nm, 22nm, 18nm, and 12nm, is best technology for many applications

  FD SOI supply comes from Globalfoundries and Samsung

CONCLUSION (CONTINUED)

- ***There are major benefits from China to support adoption of FD SOI for high-volume products that need low power consumption, RF connectivity, and analog-centric mixed-signal designs***

  FD SOI can provide product differentiation and optimize competitiveness of end designs, which is important in global markets as well as China market

- It is important to develop new architectures that utilize ultra-low-power benefits of FD SOI at 12nm in order to give lower cost products than FinFETs for AR and other AI-centric mobile applications

  VeriSilicon is already demonstrating leadership capabilities in new architectures

  HiSilicon is one of global leaders in semiconductor design at 7nm for smartphones and other applications

THERE ARE MANY AREAS OF HIGH-GROWTH OPPORTUNITIES WITHIN SEMICONDUCTOR INDUSTRY, AND CHINA REPRESENTS KEY MARKET