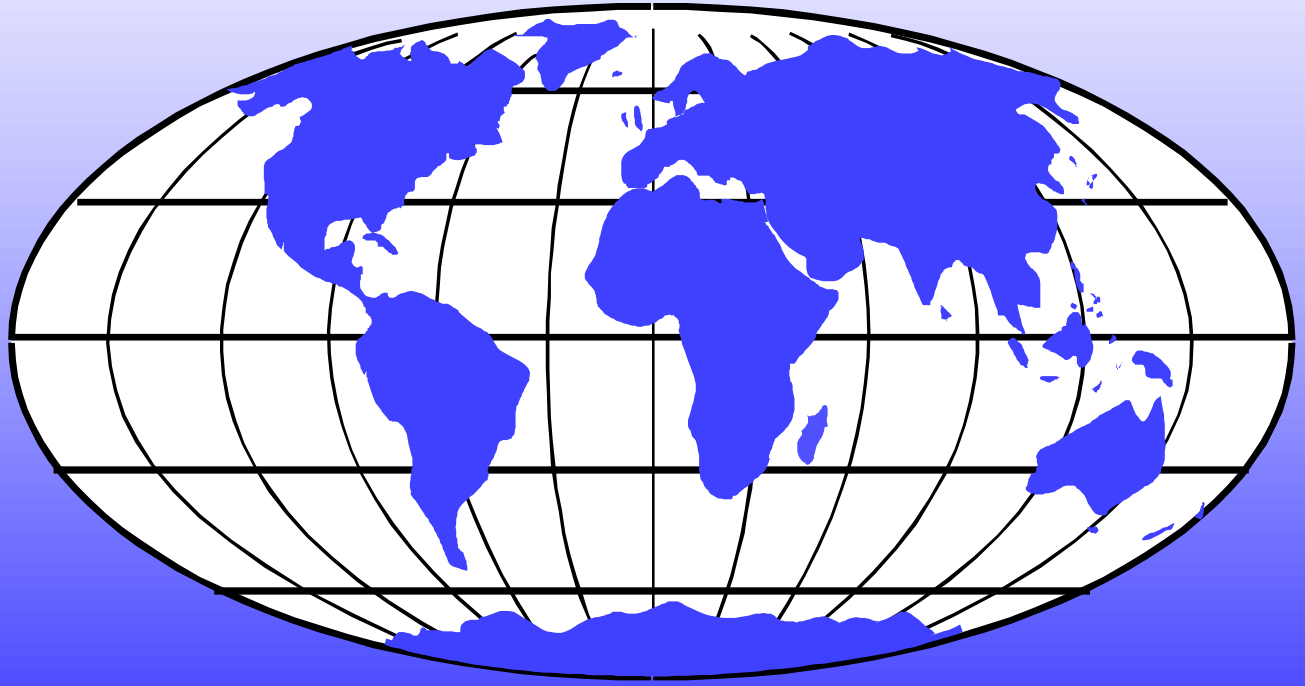
FD-SOI OPPORTUNITIES IN DEEP LEARNING AND ARTIFICIAL INTELLIGENCE APPLICATIONS

SEPTEMBER 26, 2017



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INTERNATIONAL BUSINESS STRATEGIES BACKGROUND

IBS

- Has been in business for over 29 years
- Previous experience in managing 1.5K+ engineers at Rockwell International, which included avionics, communications, and semiconductors. Strong emphasis on communications
- Interface with most global leaders in electronics industry, with customers in U.S., Europe, South Korea, Japan, Taiwan, China, India, etc
- Interface and support for 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, and others
- Interface and support for 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
- Participated with French government on their advanced technology initiatives
- Involved with advanced technology concepts, price-sensitive platforms for smartphone and other high-volume platforms, and high-performance infrastructure companies on global basis
- Strong expertise in China. Published two books on China: *China's Globalization* (*How China Becomes No. 1*) and *Chinamerica* (McGraw Hill). Forbes blog contributor, China Daily articles, Global Times editorials, EE Times, etc
- Involved in number of due diligence projects on number of IPOs
- Support for strategic initiatives for number of global technology leaders

IBS HAS HIGH MARKET SHARE ON TECHNOLOGY AND STRATEGY BUSINESS

SEMICONDUCTOR MARKET BY PRODUCT

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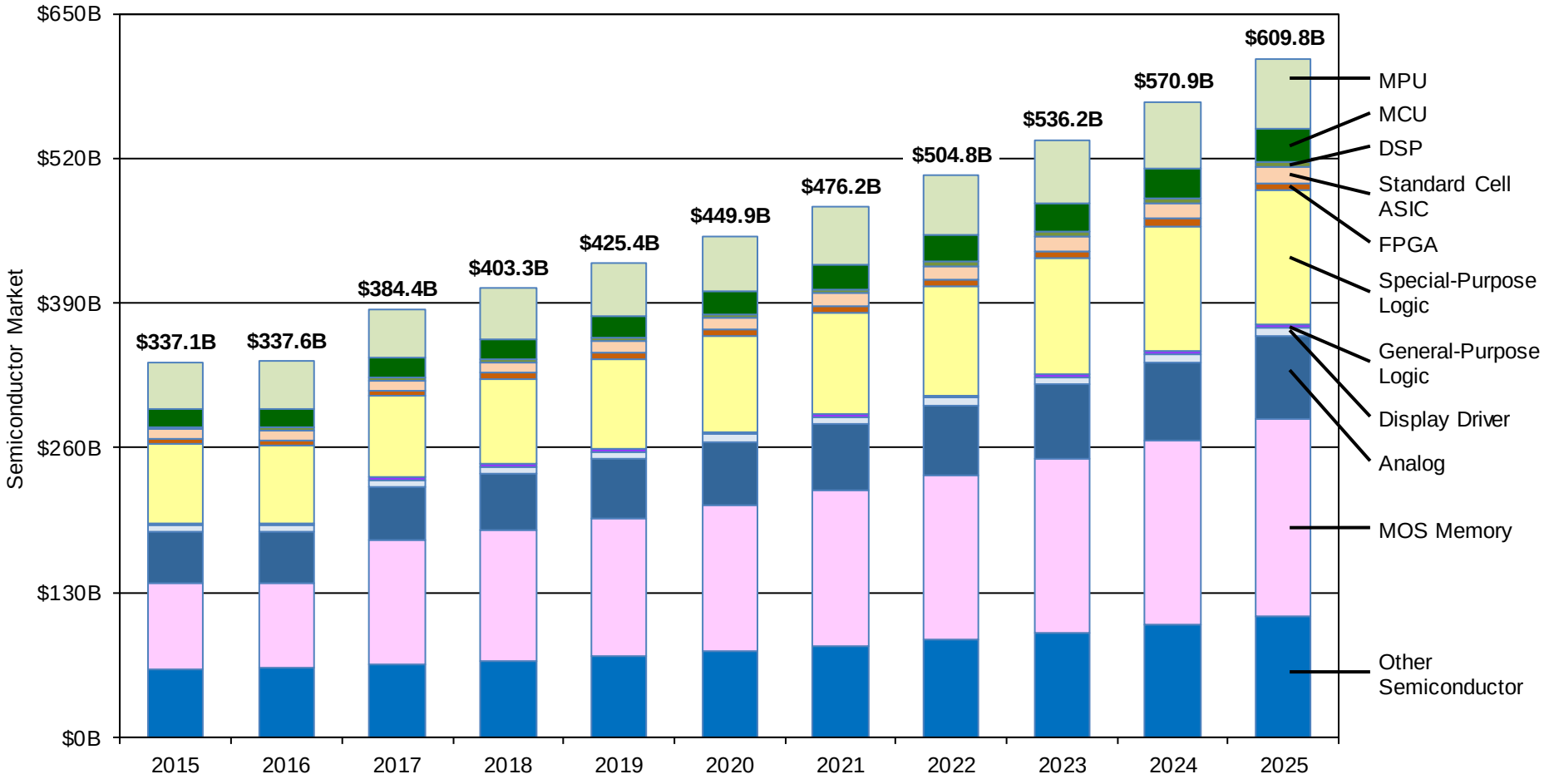

STEADY GROWTH THROUGH 2025, BUT HIGH PROBABILITY OF DOWNTURN IN INTERMEDIATE TIME FRAME

CHINA'S SEMICONDUCTOR MARKET BY PRODUCT

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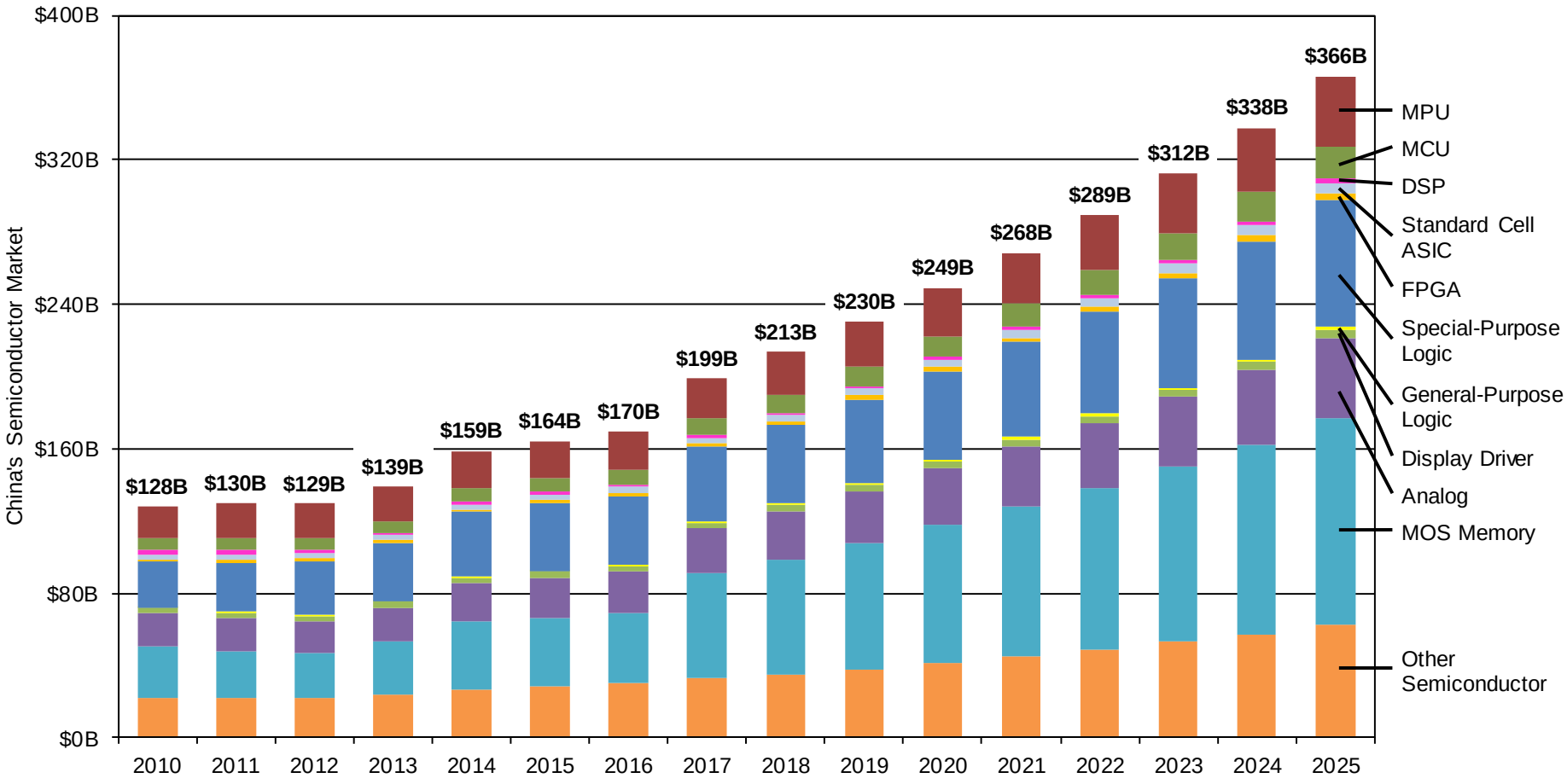

HIGHER GROWTH THAN OVERALL SEMICONDUCTOR MARKET

STRATEGIC FACTORS RELATED TO DEEP LEARNING AND ARTIFICIAL INTELLIGENCE

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- Electronics industry is going into data monetization phase, and key examples include Alibaba, Tencent, Baidu, Google, Amazon, Facebook, and others

  Chinese companies are very active in big data

- Data is generated from billions of sources

  Some applications such as autonomous driving, gaming, and HD video will create very large amount of data

- Analysis of data (analytics) can provide high value for data, with need for enhancements in deep learning and AI capabilities

- There are opportunities for data generation, processing, and display, which will provide large opportunities for semiconductor vendors

- China is leader in 5G, with projections of one billion users in 2025 to 2028

- Key requirements are high-performance processing and low power consumption, where training and inference algorithms are developed for vision, audio, and other real-time processing applications

SUPPORT CAPABILITIES FOR DEEP LEARNING AND AI WILL REPRESENT MAJOR GROWTH OPPORTUNITIES FOR SEMICONDUCTOR VENDORS IN CHINA AND GLOBALLY

KEY ISSUES IN DEEP LEARNING AND AI

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- Key product that will benefit from deep learning and AI is smartphone, with support of AR

  Image processing, which includes image segmentation and fusion and support of image recognition, requires high-performance processors that utilize deep learning and AI to analyze patterns

  Kirin 970 of HiSilicon has neural processing unit (NPU) and can perform 1.92TFLOPS (FP16)

  Apple's A11 has neural engine performing 600 billion operations per second

- Autonomous driving with levels 4 and 5 capabilities involve deep learning and AI

  NVIDIA is strong in training while Mobileye is strong in inference (use of FD-SOI)

- Smart robots, which will be used for homecare, toys, and factory automation, will require deep learning and AI technologies

- Smart glasses that support AR (HoloLens of Microsoft and others) will require deep learning and AI

  AI processors are being developed for these applications

- Smart toys will require deep learning and AI capabilities

  NeoBear is innovative example of support of AI

  Very Hungry Caterpillar is also example

IMPORTANT REQUIREMENTS ARE VERY HIGH PERFORMANCE AND LOW POWER

FD-SOI IS GOOD TECHNOLOGY OPTION

KEY STRATEGIC ISSUES IN CHINA

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- China will represent 60.0% of the global semiconductor market in 2025

  Chinese companies, eg, Huawei, Vivo, OPPO, Lenovo, and others, will consume 60.0% of semiconductors in China market in 2025 compared to 15.8% in 2010

- China will supply 65.4% of smartphones globally in 2025
- Based on existing trends, foreign companies will supply 81.2% of the semiconductor consumed in China in 2025
- China is 12 to 18 months ahead of U.S. and Europe in 5G development
- China is leader in quantum communications
- WeChat (963 million users in H1/2017) is significantly ahead of U.S. offerings

THERE IS LARGE OPPORTUNITY FOR SEMICONDUCTOR SUPPLY IN CHINA, BUT IT IS IMPORTANT TO HAVE COMPETITIVE ADVANTAGE IN SOME TECHNOLOGIES

FD-SOI IS ONE OPTION

SMARTPHONE MARKET

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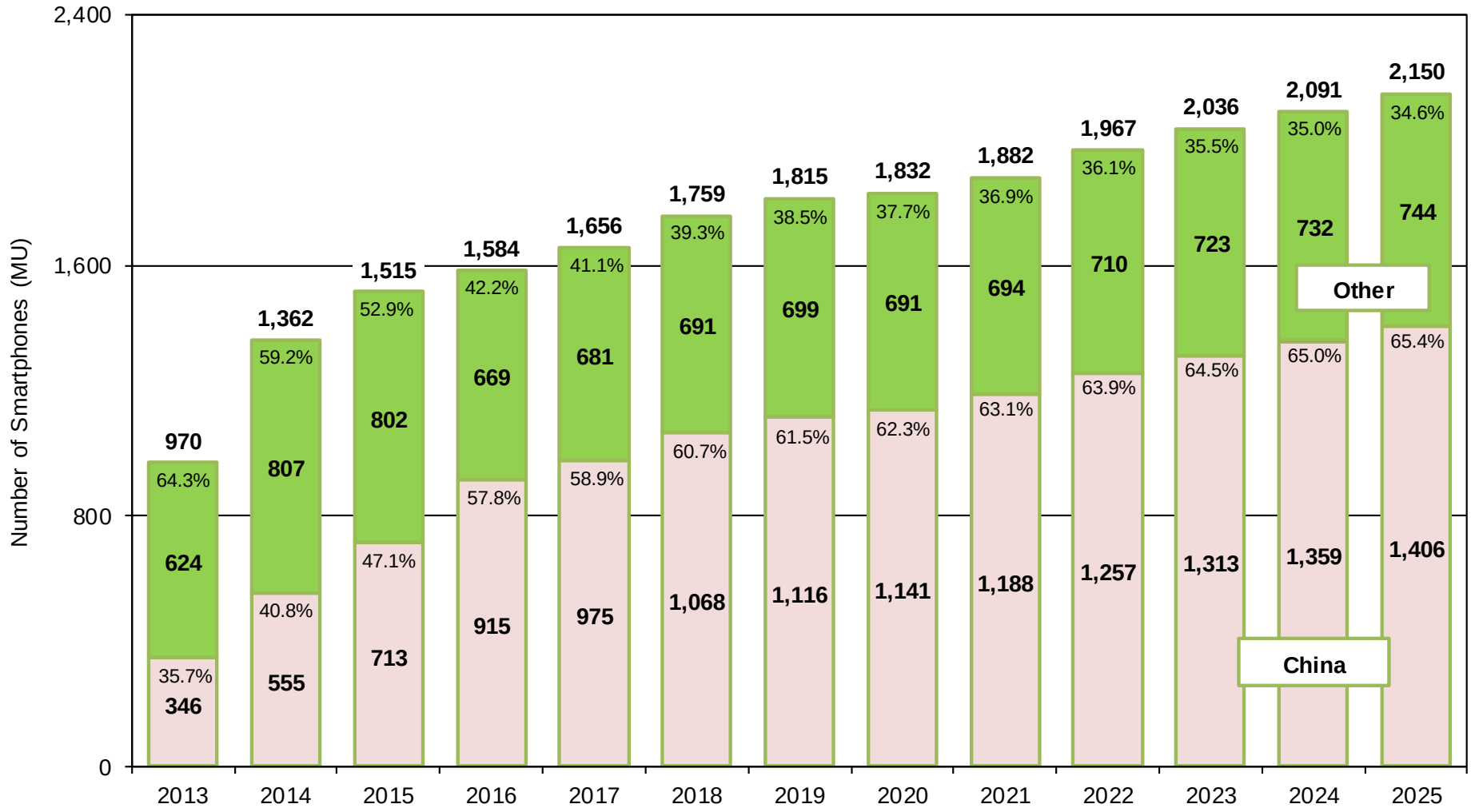

CHINESE COMPANIES WILL SUPPLY 60.7% OF TOTAL SMARTPHONES IN 2018

SEMICONDUCTOR CONSUMPTION PATTERN IN CHINA

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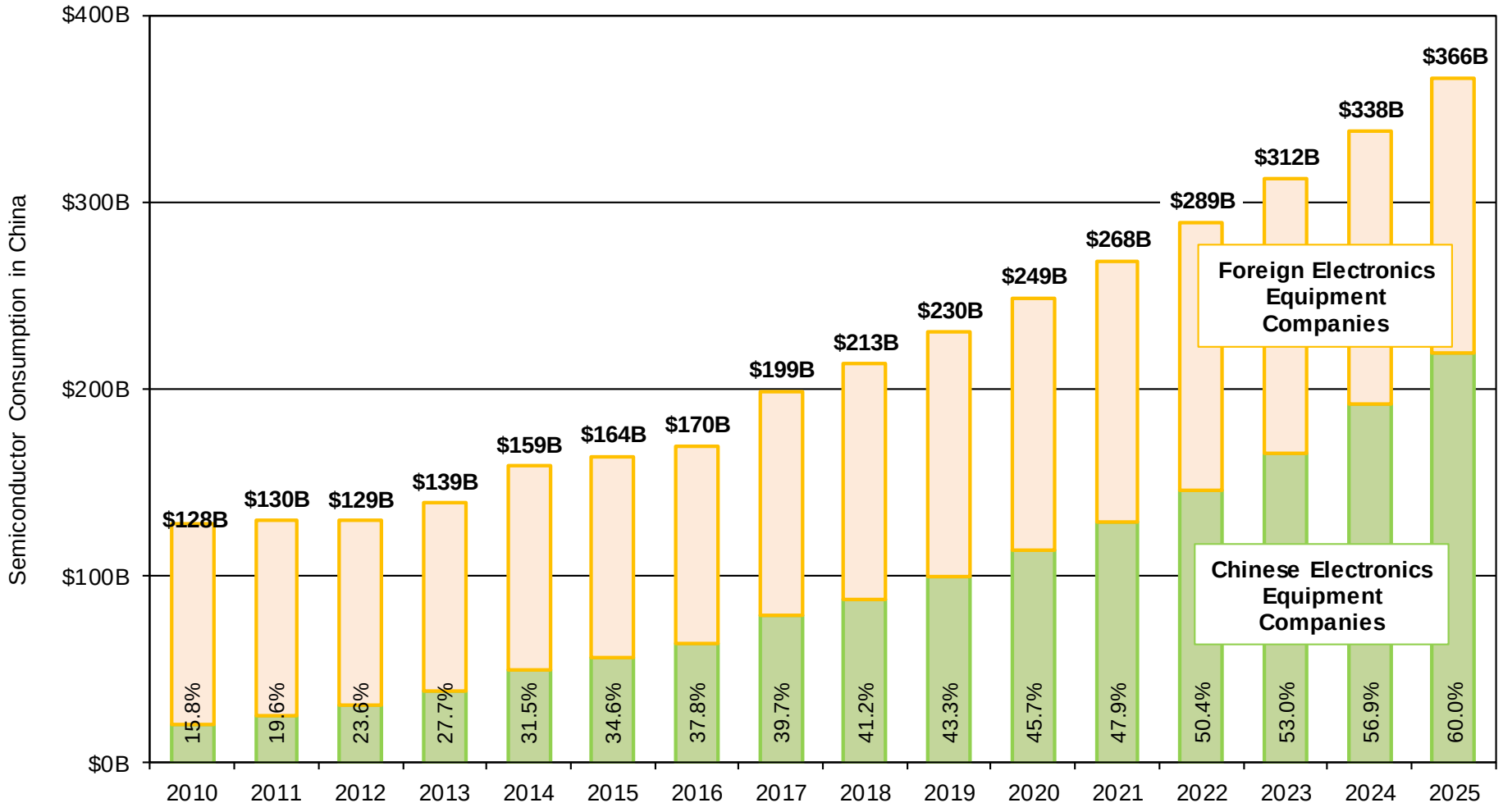

CHINESE COMPANIES CONSUMED 15.8% OF TOTAL SEMICONDUCTORS IN CHINA IN 2010 BUT WILL CONSUME 60.0% IN 2025

SEMICONDUCTOR SUPPLY IN CHINA

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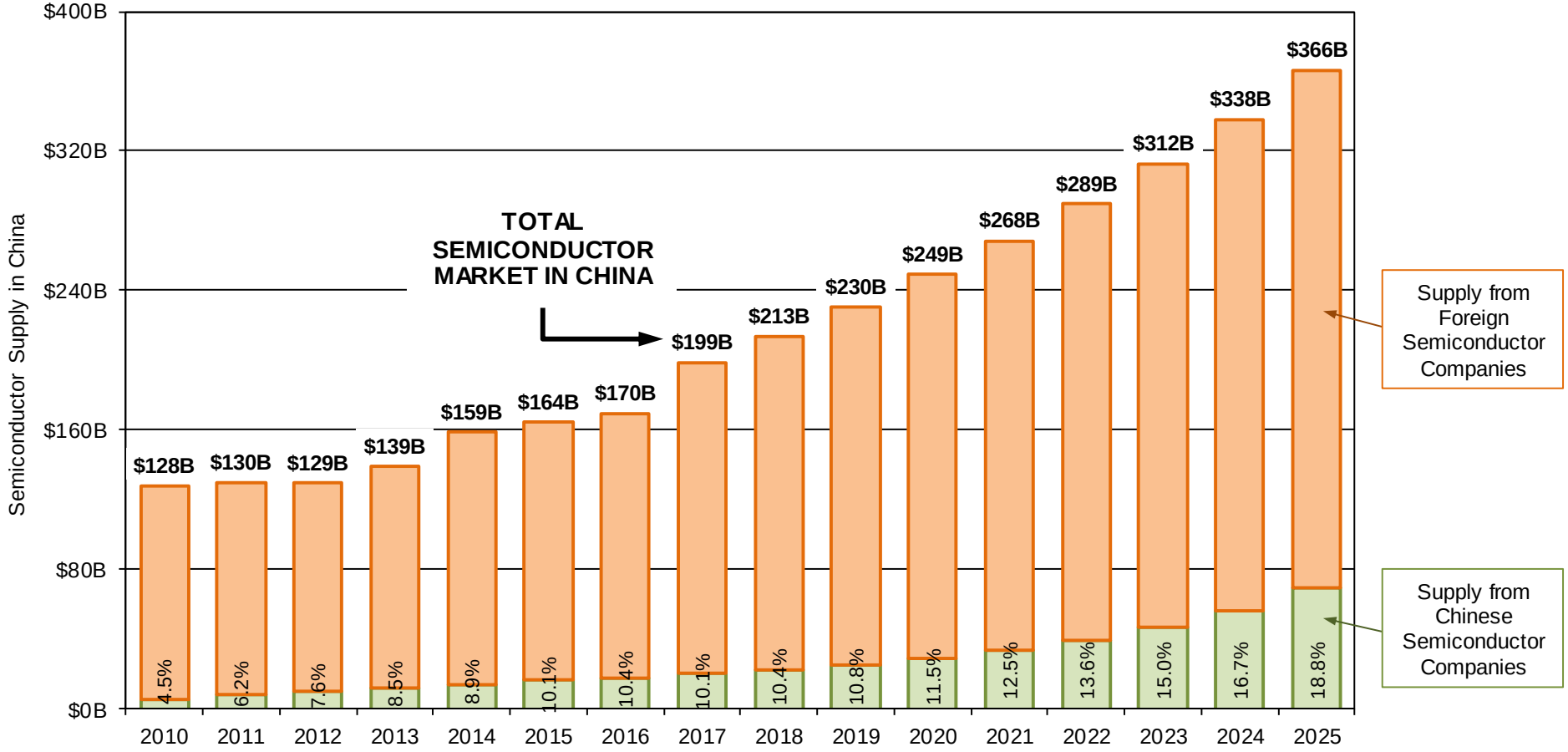

CHINESE SEMICONDUCTOR COMPANIES NEED TO STRENGTH THEIR DESIGN CAPABILITIES

COST PER GATE PERSPECTIVE

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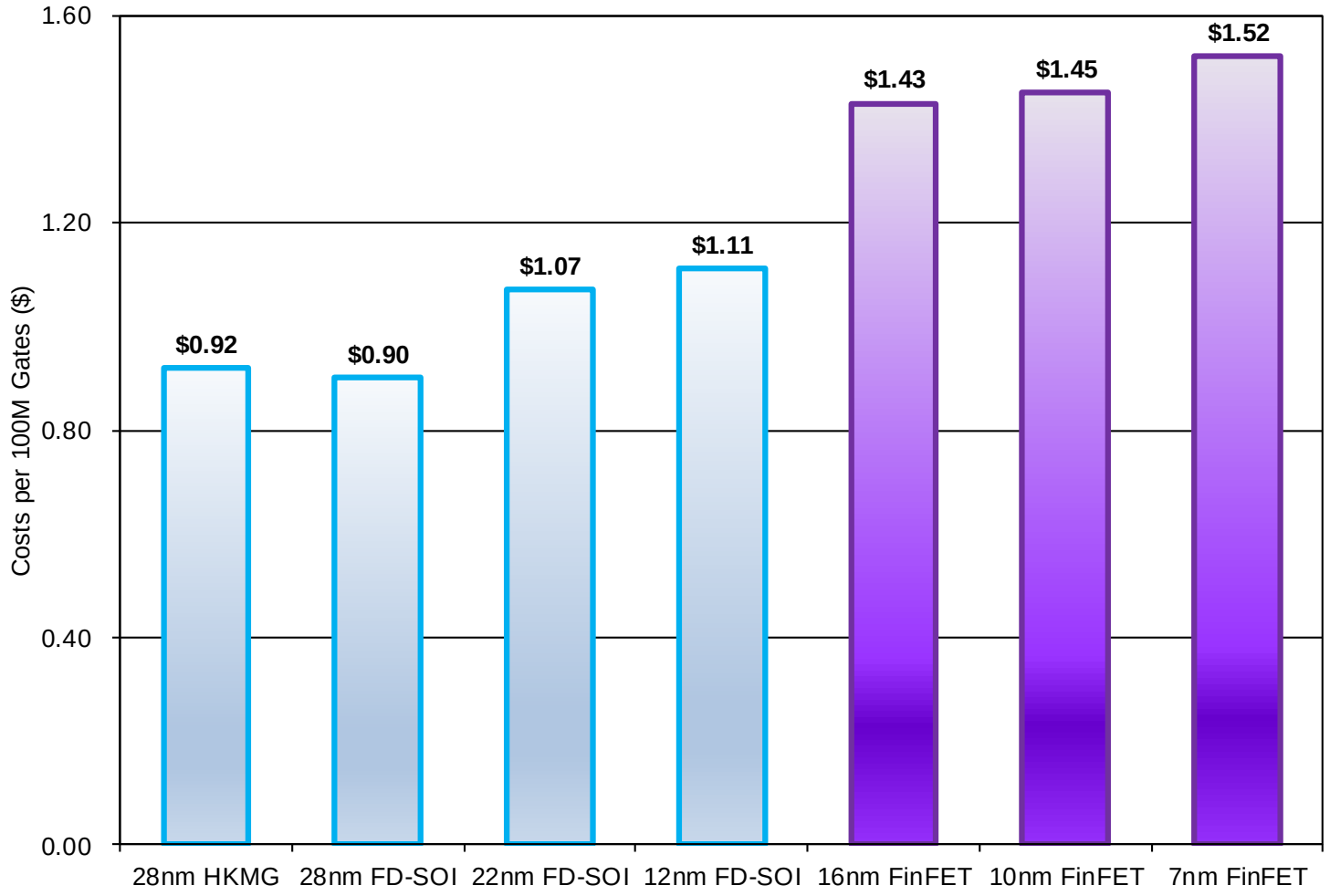

GATE COST FOR 12nm FD-SOI IS 27.0% LOWER THAN FOR 7nm FINFET

FD-SOI'S POWER CONSUMPTION WITH BACK BIASING IS ALSO LEADERSHIP

COST BENEFITS OF FD-SOI

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- Gate cost of 22nm FD-SOI is comparable to 28nm HKMG bulk CMOS

- ***Gate cost of 12nm FD-SOI is:***

  - 22.4% lower than 16nm FinFET
  - 23.4% lower than 10nm FinFET
  - 27.0% lower than 7nm FinFET

  Key reason for lower gate cost of 12nm FD-SOI is fewer number of mask steps

COST BENEFITS FOR FD-SOI PRODUCTS INCREASE AS FEATURE DIMENSIONS ARE REDUCED TO 12nm

FD-SOI PRODUCT VALUE POTENTIAL

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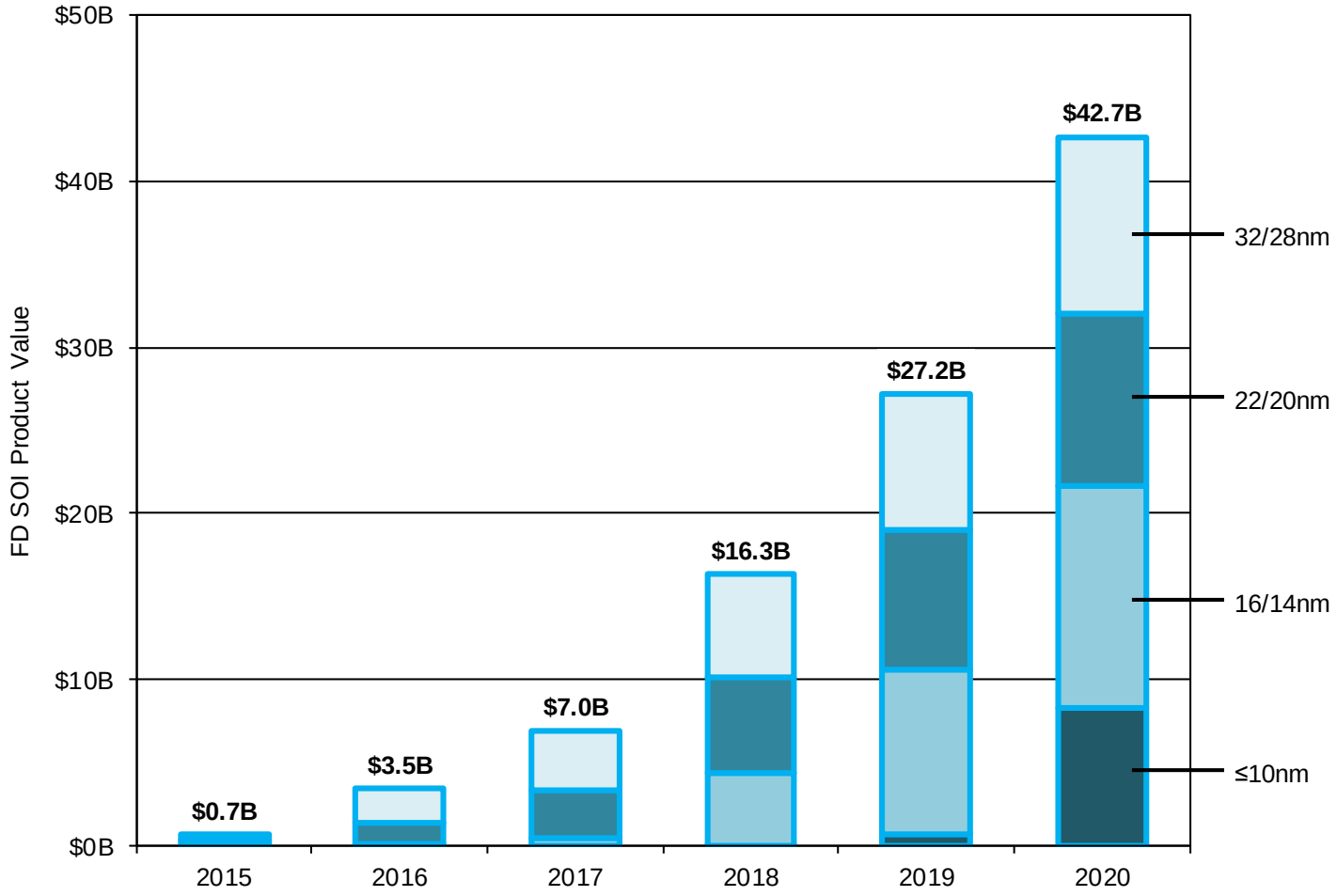

FD-SOI PRODUCT VALUE IS BASED ON LOWER COST, LOWER POWER CONSUMPTION, AND COMPETITIVE PERFORMANCE FOR HIGH PERCENTAGE OF MARKET

DESIGN COSTS (FOLLOWER)

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	28nm				22nm				16/14nm				10nm			
	%	Engr. mos.	Loaded cost/eng	TOTAL cost	%	Engr. mos.	Loaded cost/eng	TOTAL cost	%	Engr. mos.	Loaded cost/eng	TOTAL cost	%	Engr. mos.	Loaded cost/eng	TOTAL cost
Hardware																
• IP qualification	17.6	123.7	0.194	2.000	17.4	172.6	0.196	2.819	17.3	298.7	0.201	5.003	20.6	557.1	0.204	9.471
• Architecture	6.5	45.7	0.229	0.872	7.5	74.5	0.231	1.434	6.8	117.6	0.233	2.283	8.0	215.8	0.237	4.262
• Verification	49.5	347.6	0.224	6.489	47.3	469.4	0.227	8.879	49.0	844.3	0.248	17.449	43.1	1,163.4	0.252	24.431
• Physical	26.3	184.8	0.225	3.465	27.8	276.1	0.228	5.246	26.8	462.5	0.229	8.826	28.3	764.3	0.231	14.713
Subtotal hardware (design engineering resources)	100.0	701.8		12.825	100.0	992.6		18.379	100.0	1,723.1		33.562	100.0	2,700.6		52.877
Software		561.3	0.176	8.232		763.8	0.182	11.584		1,278.1	0.194	20.663		2,947.6	0.197	48.390
Prototype cost ($M)	1.987				2.978				5.027				10.963			
Validation of prototypes		277.5	0.223	5.157		376.3	0.229	7.181		611.7	0.243	12.387		947.9	0.242	19.116
TOTAL		1,540.6		28.202		2,132.7		40.122		3,612.9		71.638		6,596.1		131.346

DESIGN COST OF 12nm FD-SOI IS ESTIMATED AT $50 MILLION TO $55 MILLION COMPARED TO $72 MILLION FOR 16nm FINFET

10nm FINFET DESIGN COST IS $131 MILLION

REVENUES NEED TO BE 10X DESIGN COSTS, GIVING LARGER TAM FOR FD-SOI COMPARED TO 16nm AND 10nm FINFETS

CONCLUSION

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- FD-SOI can give lower gate cost than FinFETs, with comparable performance and power consumption (applies to 12nm FD-SOI and 16nm, 10nm, and 7nm FinFETs)
- Also, FD-SOI can give lower design cost than FinFETs because of reduction in parasitics that must be compensated for

  RF, eNVM, and analog-centric mixed-signal structures are much more effective when implemented within FD SOI processors (28nm, 22nm, 18nm, and 12nm) than FinFETs
- Adoption of FD-SOI has been slow because large wafer fab capacity was not available and IP and design ecosystem were not established, but this situation is changing

  Benefits of FD-SOI are also not well understood due to limited availability of silicon-based products that could demonstrate benefits
- Mainstream wafer vendors had overly optimistic impressions of FinFETs, and this resulted in strong support by fabless semiconductor vendors

  FinFETs can be effective for many applications, but with cost penalties (gate and design costs)
- 28nm, 22nm, 18nm, and 12nm FD-SOI will have lifetime of 20+ years

  Key requirement is to develop design skills for effective use of FD-SOI, which includes use of back biasing and strong portfolio of IP

WIDE RANGE OF PRODUCT FUNCTIONALITY CAN BE SUPPORTED BY FD-SOI, AND MOMENTUM IS BUILDING