International Technology Roadmap for Semiconductors

Juan-Antonio Carballo, ITRS Design ITWG

SMTAI, Orlando, FL

10/12/07

Advancing manufacturing technology

ITRS Roadmap Design + System Drivers

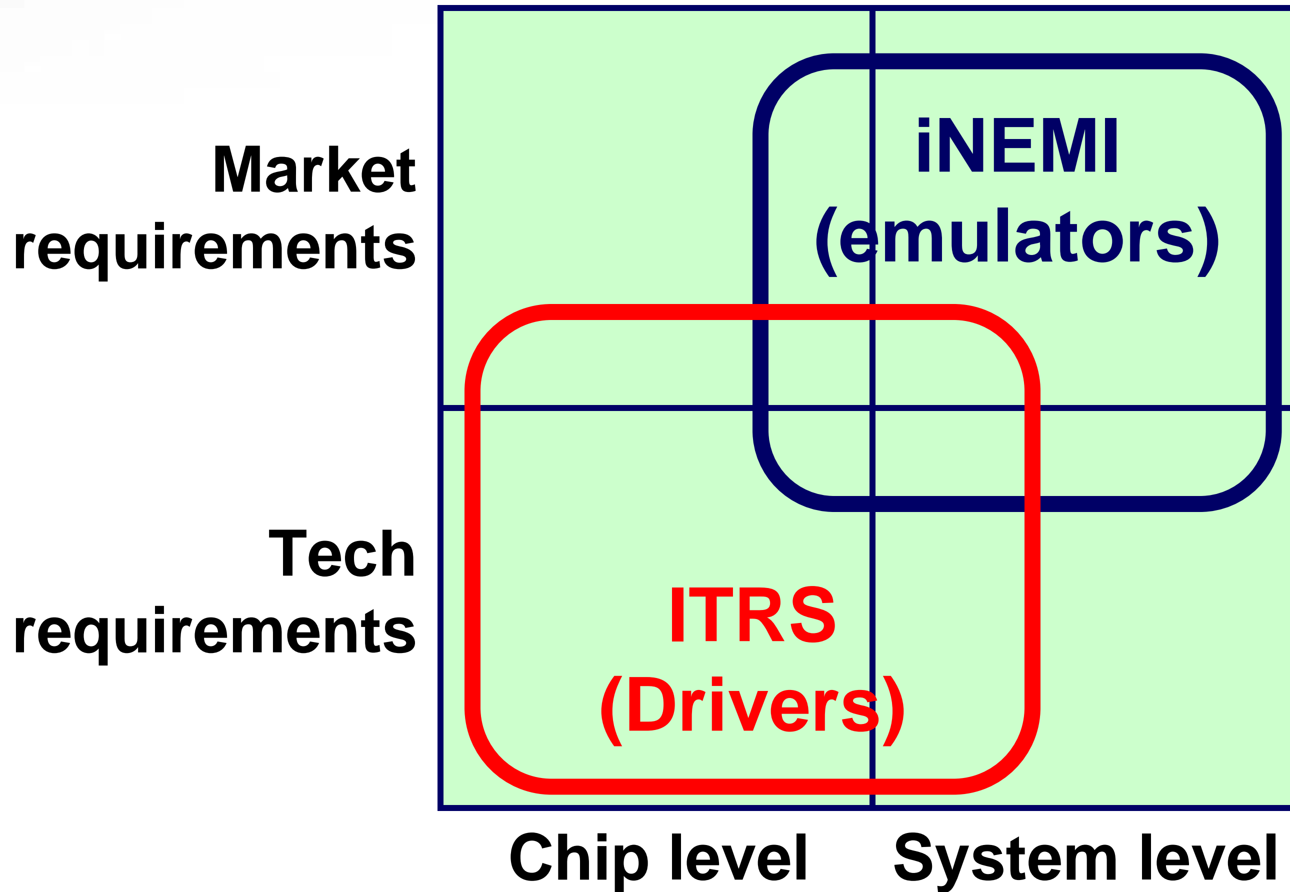
The New Scaling of Silicon Systems

iNEMI October Meeting, Orlando

Worldwide Design TWG

Presented by Juan-Antonio Carballo

ITRS-iNEMI Domain Space



The Message

1. ITRS Design Group focuses on roadmapping:

1. **Design Chapter:** Technology challenges and solutions
2. **System Drivers Chapter:** Types of silicon systems

2. ITRS addressing new systems scaling

Conventional **(**Moore) + Heterogeneous (Moore+) scaling

3. ITRS being aligned by market/application driver

“Fabric” drivers – market independent

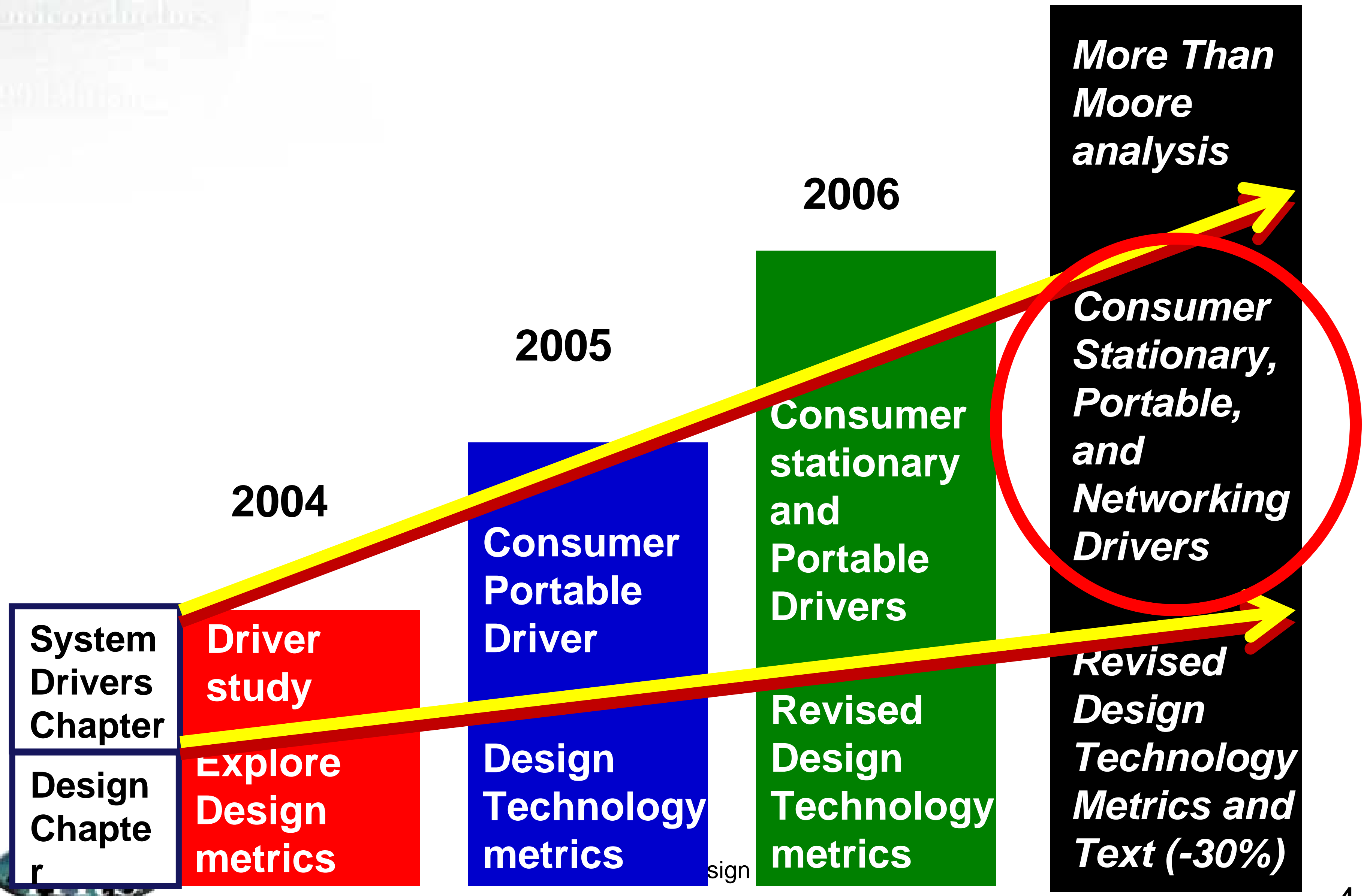
CPU, DSP/SPU, memory, AMS

With iNEMI!

“Market” drivers – market dependent

consumer mobile and stationary, networking, office

ITRS Design + System Drivers



The New Scaling of Silicon Systems

Different Market Drivers Scale Differently

Technology Waves And (VC) Investment

	70s	80s	90s	2000s	2010s
Wave	Mainframe / Mini	PC/ Client/ server	Internet Telco Enterprise	Digital media Emerging Geos Consumer	Transportation Bio/Medical Cleantech/energy Social IT

$5+B /year

$20+B /year

Source: insight from Top VCs including Walden

Driver Template

Driver parameter	Example	Units
Market requirements (customers AND suppliers)	Cost,	$ / unit
	Performance	Pages / sec
	Energy consumption / battery life	Hours
	Time to market	Months
	Reliability	Years
Critical design requirements	Power,	Watts
	Area,	mm^2
	Time per operation / clock speed	GHz
	Latency / throughput / bandwidth	Nano-secs
	Design productivity	PY/ mm^2
	Hours of operation	Hours
Critical design parameters	Memory size / bandwidth	Bytes
	# processing units, redundant units	<None>
	Size and clock speed/BW of each unit	Mm^2
	Number of pins	<None>

System (Market) Drivers Evolution

Driver	Market ST/LT requirements	Design requirements	Design parameters	Leader
Office/PC (processor)	**(General) Performance**	Clock cycle MIPS, FLOPS	#of cores memory	**US 2005**
Consumer (portable) **Consumer (stationary)**	**Energy** **cost** **(Media/emerg) performance**	W, hours of operation (energy) Frames/sec, FLOPS	# of cores, voltage, clock cycle, etc. # of SPUs, memory BW, etc,.latency	**Asia 2005 (Japan)** **Asia 2006 (Japan)**
Network (comms.)	**Bandwidth**	G/Tbits/sec	# of I/Os, BW per I/O, etc.	**US 2007**
Automotive (industrial)	**Reliability** **Accuracy**	Years, max/min T, radiation, sensing accuracy	% redundancy	**EU 2008**
Medical	Heterogeneous **Integration**?	Analog, digital, chemical, bio, sensors, etc.	#of (bio, chem) sensors on-chip,	**EU 2008**
Defense	**Reliability (extreme)**	Years, max/min T, radiation,	Redundancy	**USA 2009**

Process For Each System Driver

Synch with iNEMI market emulators

Industry data

1

Identify market requirements

Cost | Perf.

Identify design requirements

Power
Area
Hrs. operation

Select DRIVER requirements

Power

2

Identify key design parameters

#units
Size per unit
Memory
Pins

Select Critical/difficult parameters

3

Create model
Generate data
Color data

#units
Size of each unit
Number of pins

Template Plan For System Drivers

	ISSCC (USA) FEB	Spring (EU) APRIL	Summer (USA) JULY	ICCAD (USA) NOV	Winter (Asia) DEC
Process	Agree				
Market and design reqs and parameters	Discuss line items	Agree on line items			
Tables		Have some data	Have all data		Plan next year
Text			Have some text	Text finished, link to chapters	

An Expanded Set of Drivers Will Direct An Increasingly Broad Industry

Fabrics

SW ?

MPU

PE(DSP)

Memory

AMS

2008 | 2007-8 | 2006 | 2007 | 2006 | 2006 | 2008

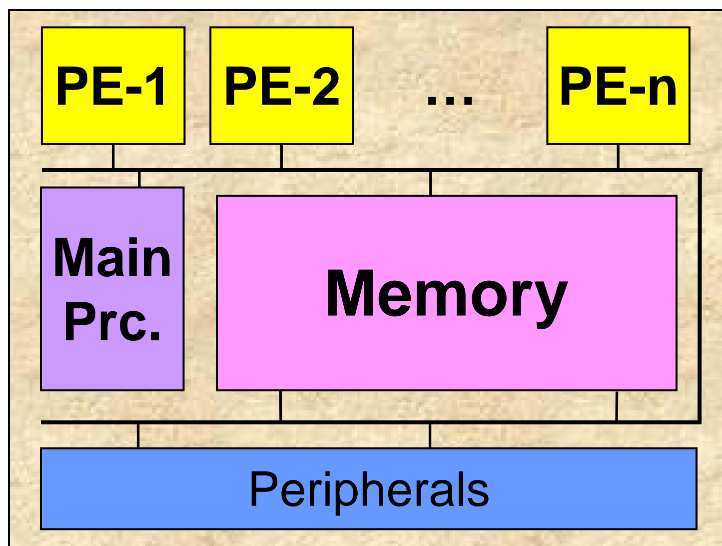
Medical | Automotive | Office | *Network* | Consumer Portable | Consumer stationary | Defense

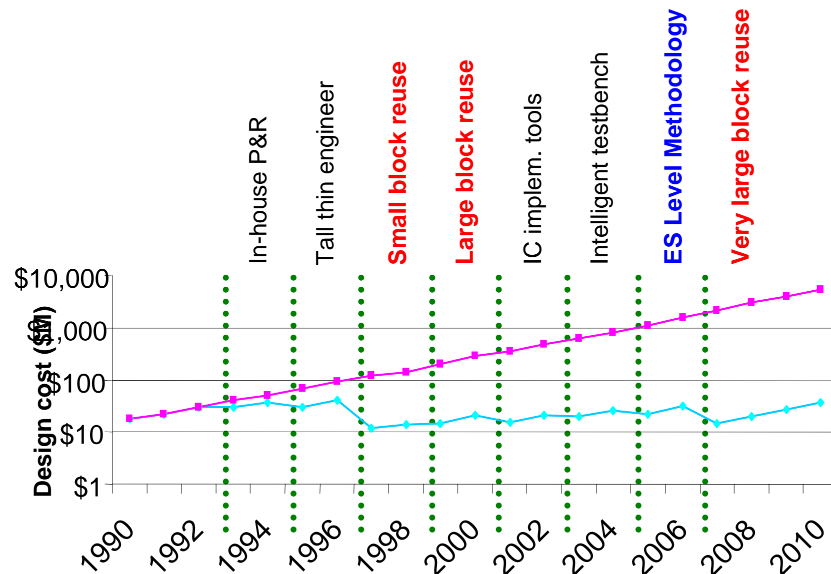
Markets

The New Scaling of Silicon Systems

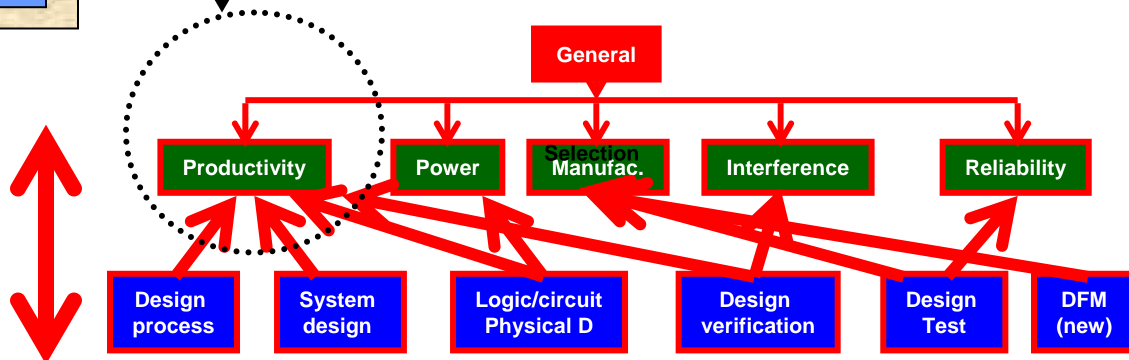
Consumer Market Driver -- Portable

Consumer Portable System Driver
(Japan Design TWG)



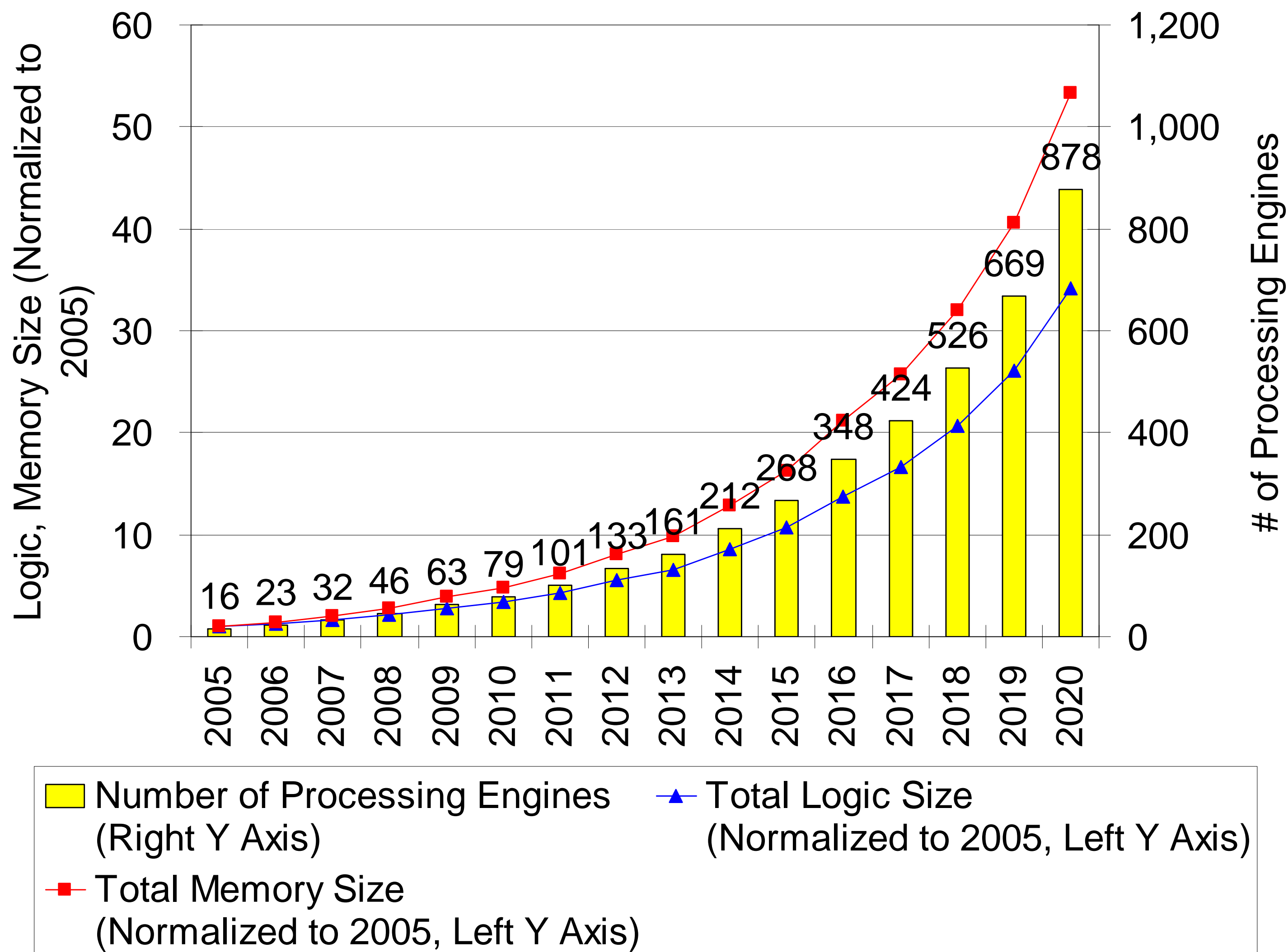


Updated productivity table → cost



Preserve consistency

--- Design Complexity Trends *(cont.)*

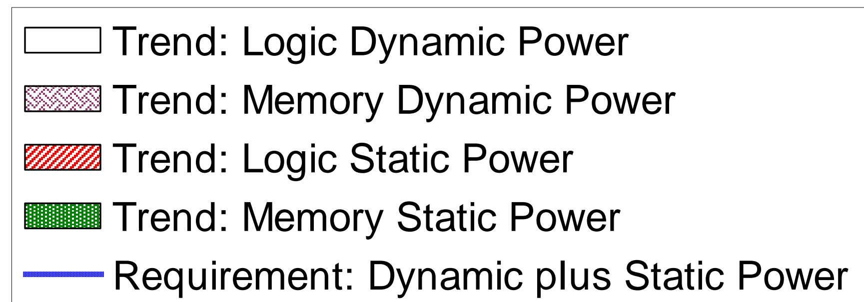


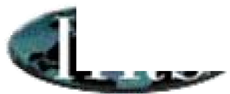
--- Power Trends *(cont.)*

Power [mW]

8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020





Processing Performance Trends *(cont.)*

of Processing Engines, Device Performance
(Normalized to 2005)
Processing Performance,

1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00

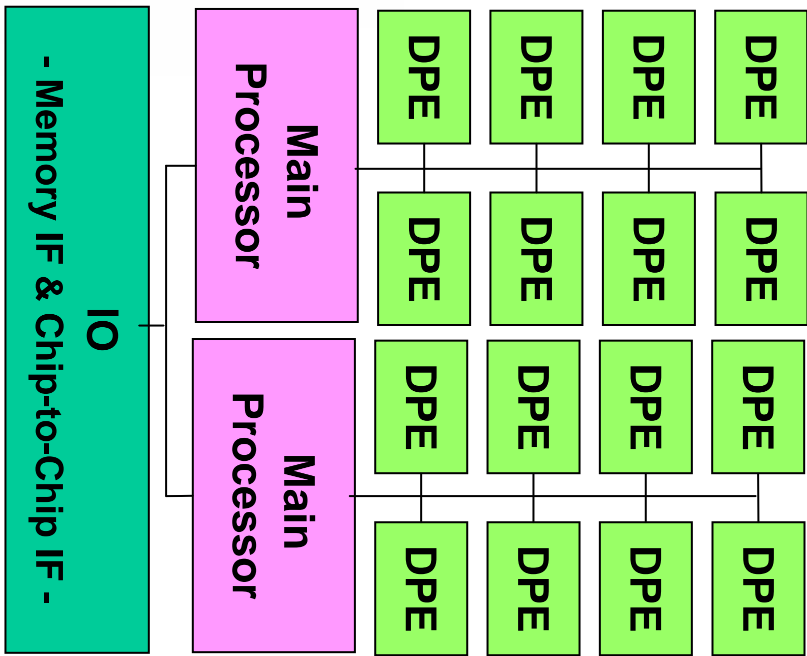
2005 2007 2009 2011 2013 2015 2017 2019

# of Processing Engines(Normalized to 2005)
Device Performance (Reciprocal of CV/I, Normalized to 2005)
Trend: Processing Performance (Normalized to 2005)
Requirement: Processing Performance (Normalized to 2005)

The New Scaling of Silicon Systems

Consumer Driver - Stationary

Architecture Template



- SOC die size stays constant around 220mm2
- Pair of a Main Processor and a number of DPEs structures basic architecture
- Possible largest number of DPEs will be on this SOC to achieve required performance
- Circuit size of both Main Processor and DPEs stys constant
- A Main Processor is assumed to be able to control up to 8 DPEs

Design Trend: # of Processors & Processing Performance

Max Processing Performance [TFLOPS]

# of Components

0
50
100
150
200
250
300

Max Processing Power [TFLOPS]

0.1
1
10
100

0.256
0.8
2.0
10.1
73

5
8
8
13
16
24
29
39
47
61
77
99
120
149
189
248

2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

Year of Production

# of Main CPUs
# of DPEs
Max Processing Performance

Performance Trend

1000

100

10

1

0.1

Trend, Nomarized to 2006

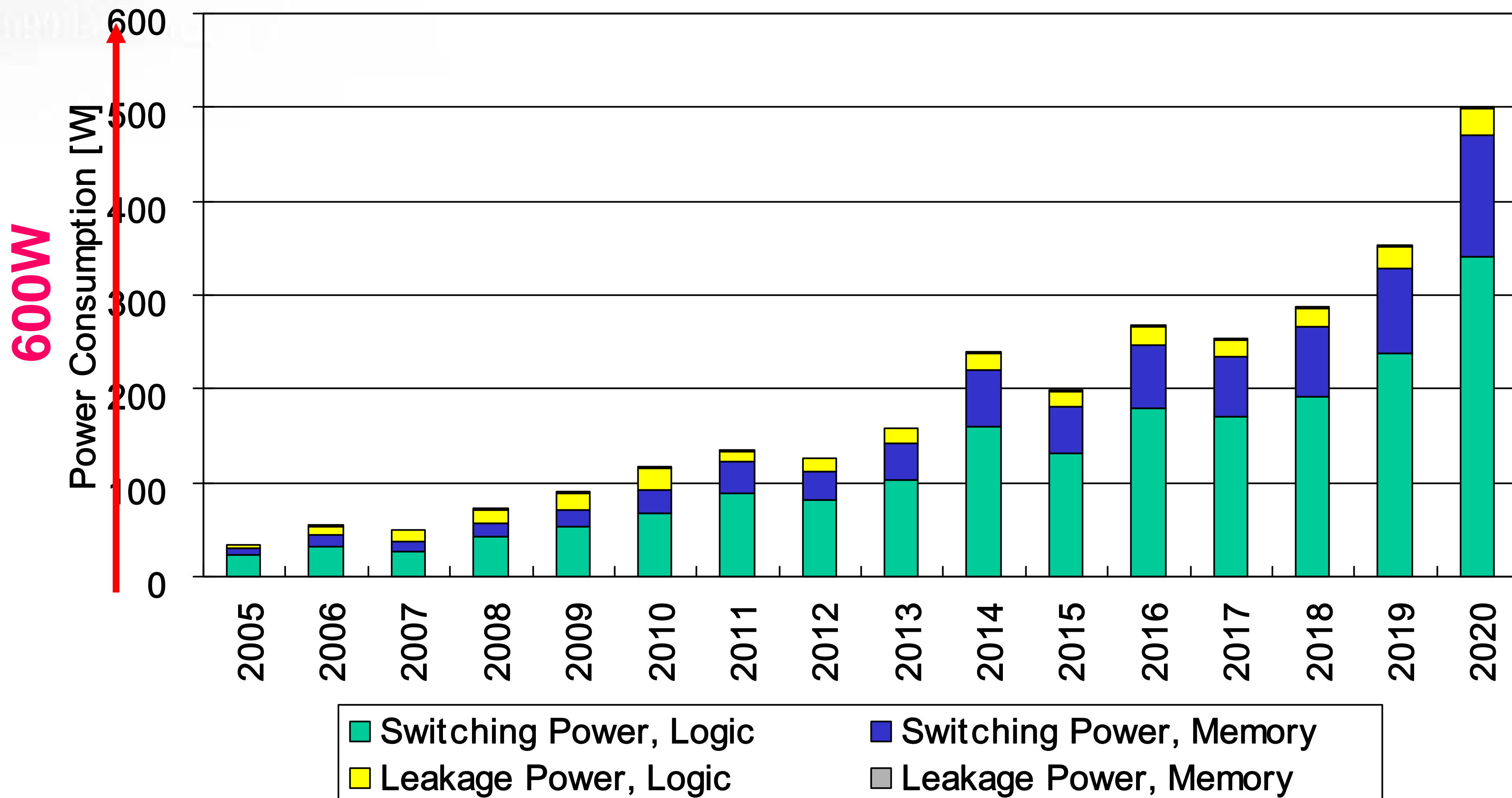
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

Year of Production

# of DPEs — 1/ τ : intrinsic switching speed — Processing Performance

Design Trend: Power Consumption – SOC Total

SOC total power consumption rapidly increases



The New Scaling of Silicon Systems

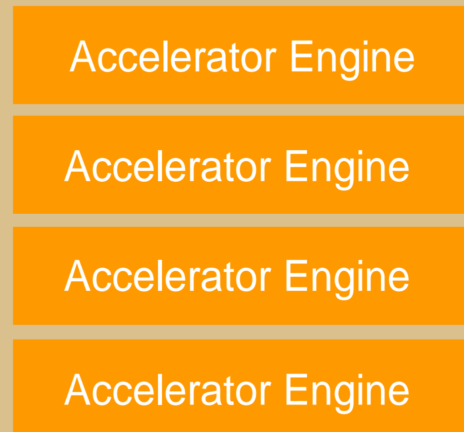
Networking Driver

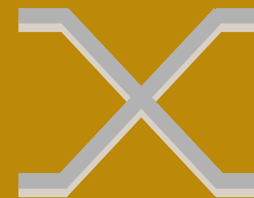
New *Networking* System Driver

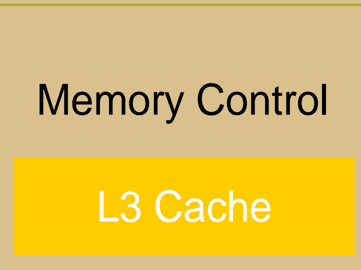
Multi-Core/Accelerator Engine SoC - Architecture template

Goals
- -Performance
- -Ease of use

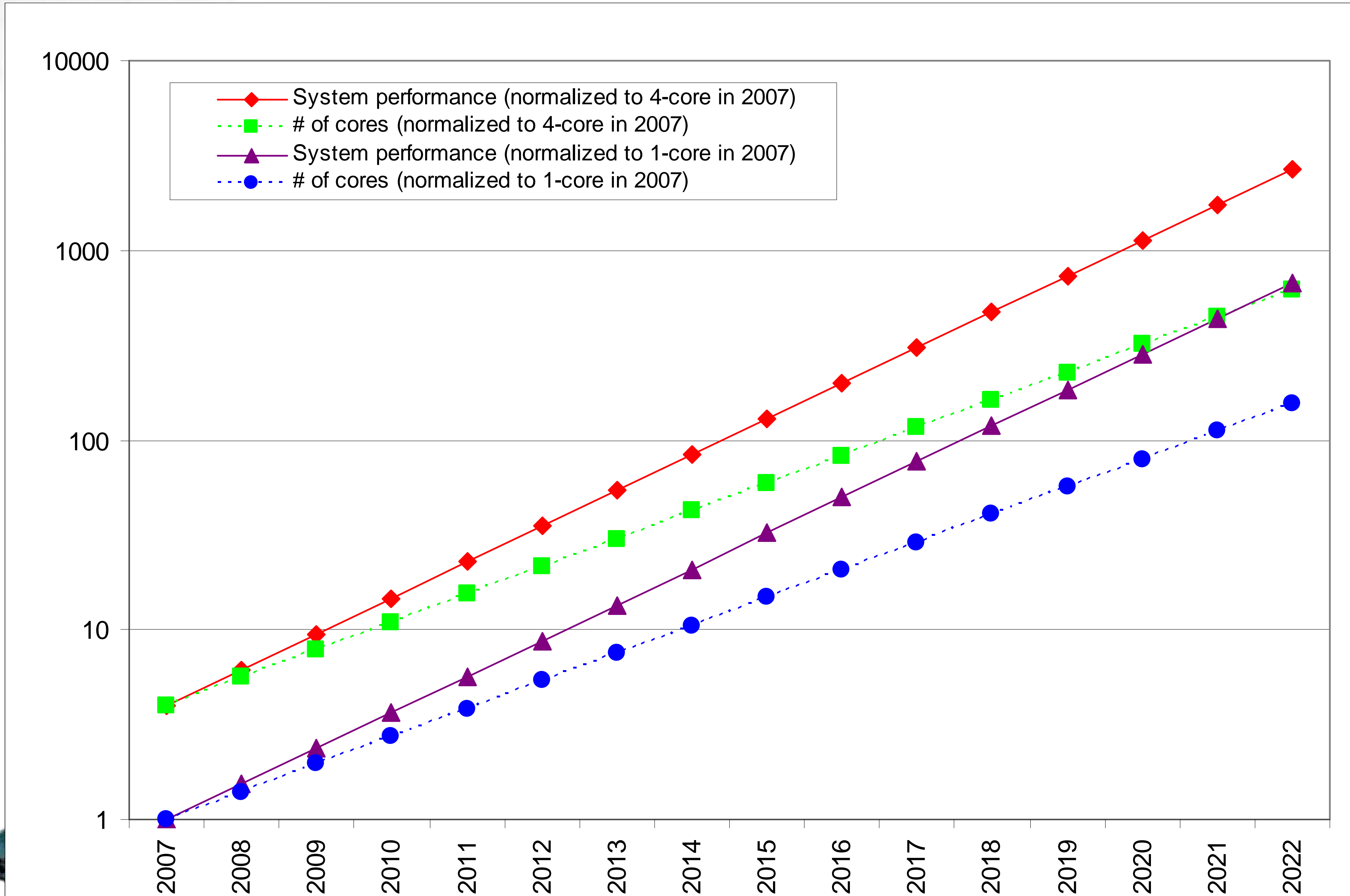
Components
- **-** On-chip fabric
- -32+ cores with private memory
- -Accelerator engine app-specific







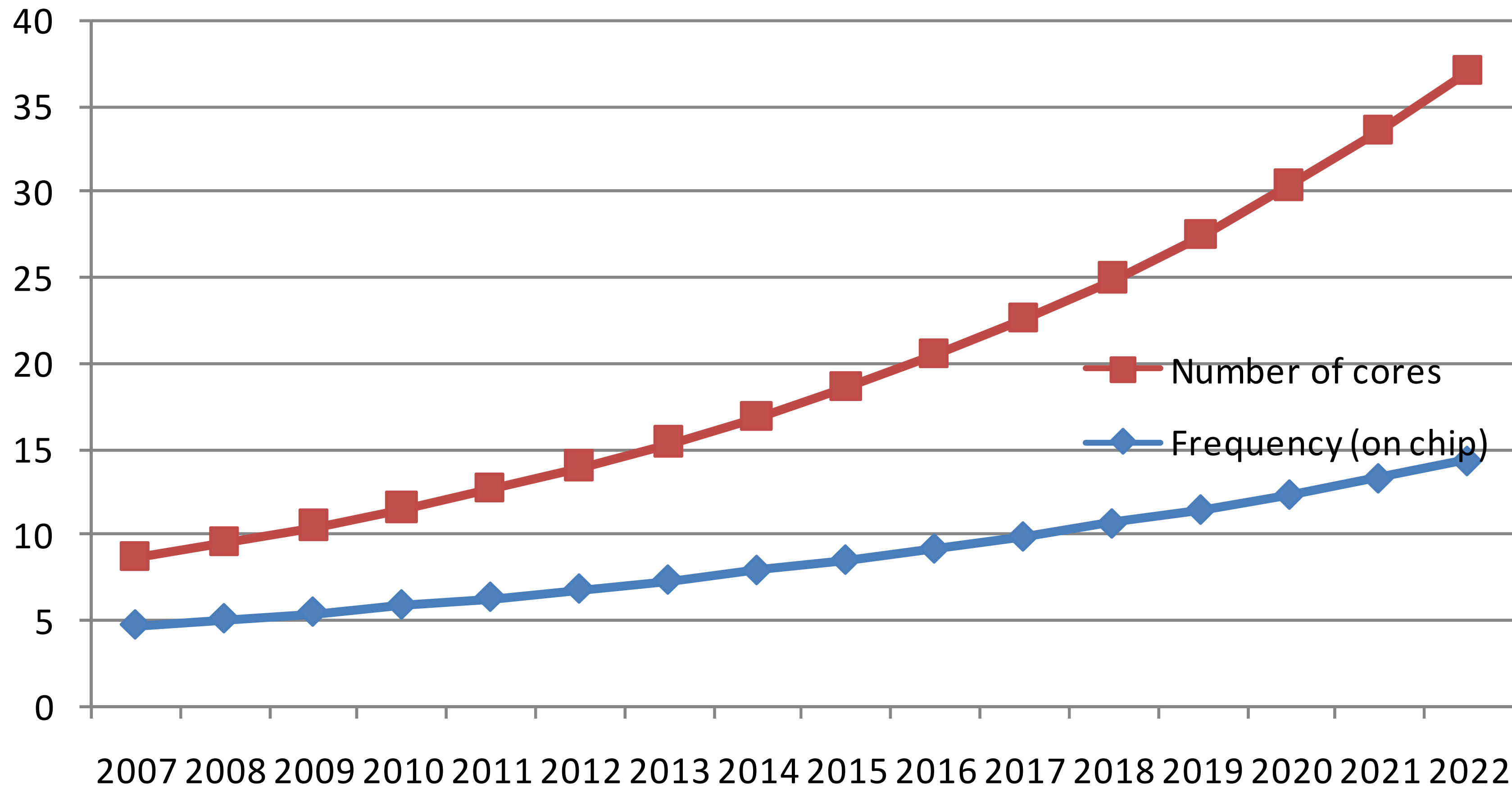
Networking Driver Trends



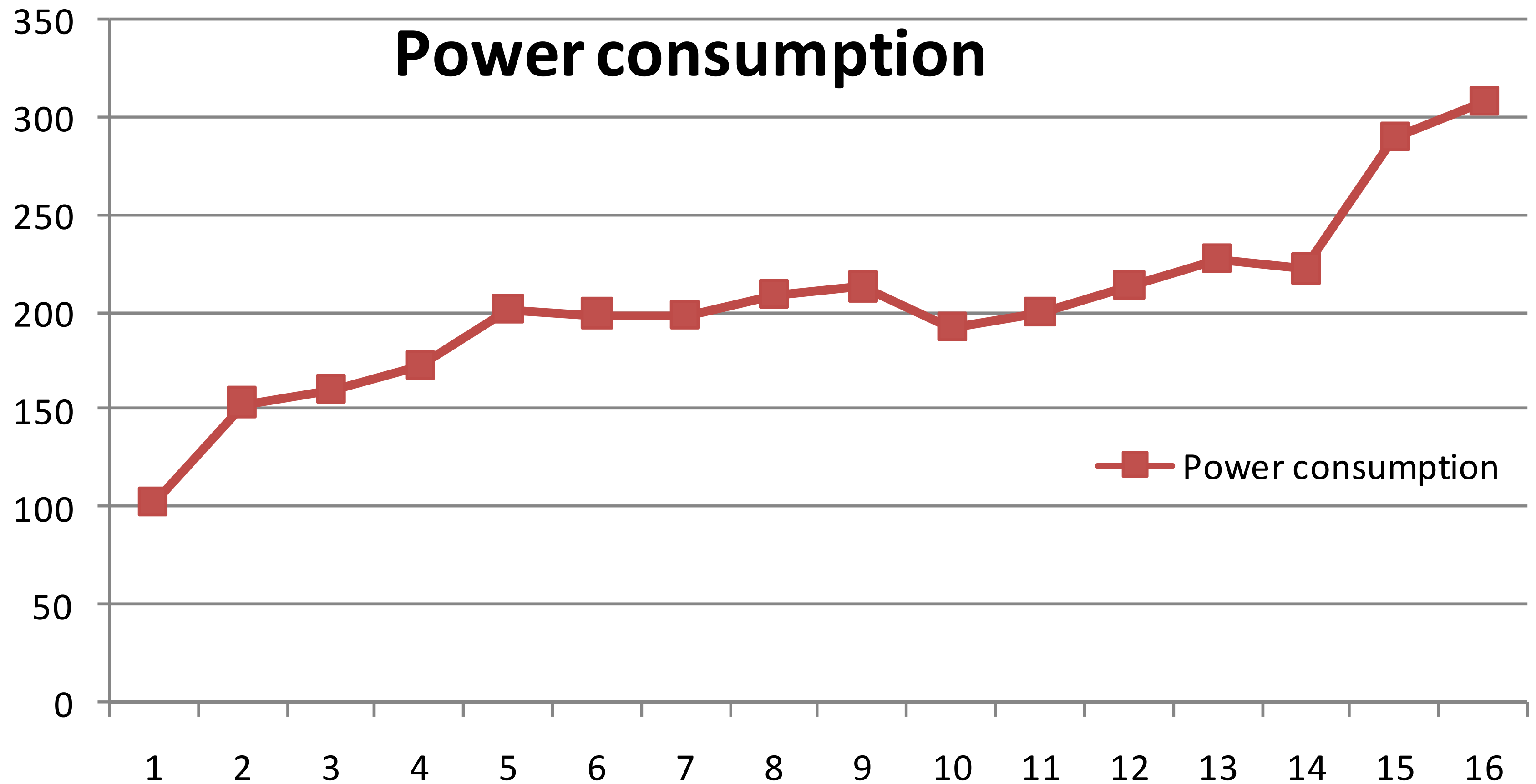
The New Scaling of Silicon Systems

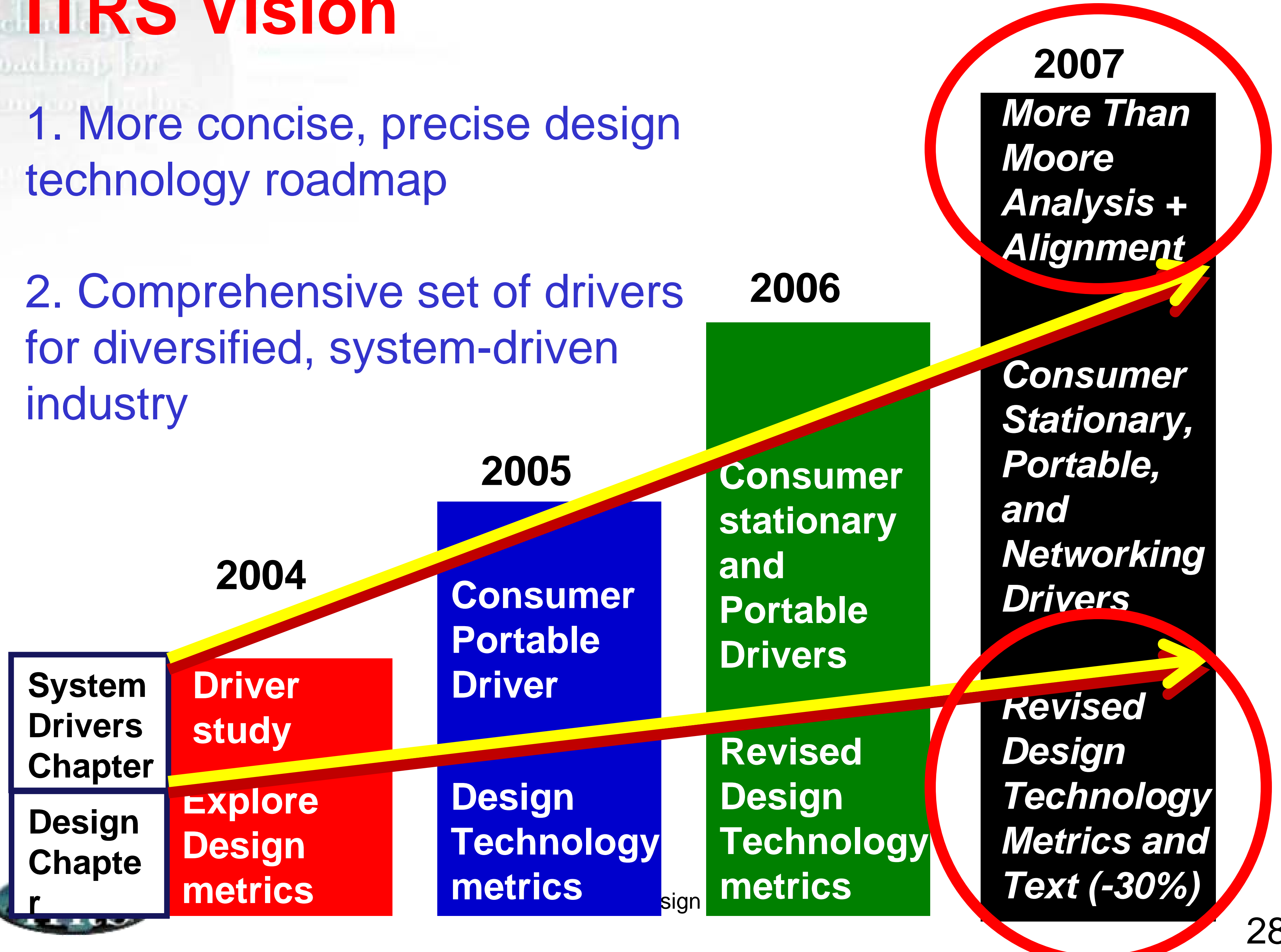
Office / MPU Driver

Office (MPU) Driver (Updated)



Office (MPU) Driver (Updated)




ITRS Vision
1. More concise, precise design technology roadmap
2. Comprehensive set of drivers for diversified, system-driven industry
2004
2005
2006
2007
System Drivers Chapter
Design Chapte r
Driver study
Explore Design metrics
Consumer Portable Driver
Design Technology metrics
Consumer stationary and Portable Drivers
Revised Design Technology metrics
More Than Moore Analysis + Alignment
Consumer Stationary, Portable, and Networking Drivers
Revised Design Technology Metrics and Text (-30%)

The New Scaling of Silicon Systems

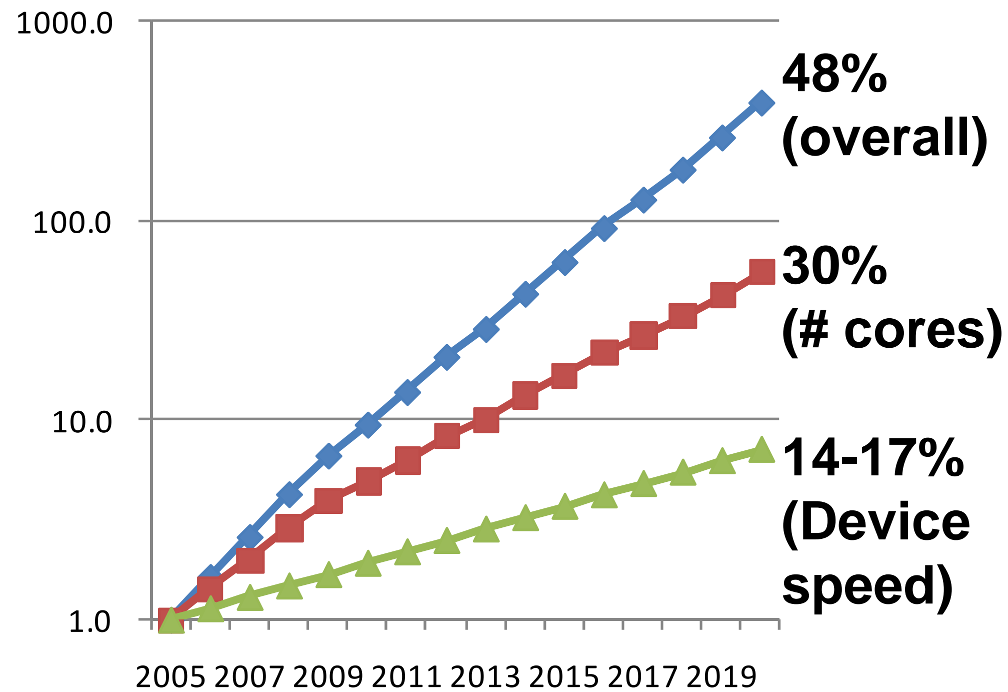
“More Than Moore” Versus “Moore’s Law”

Design-Driven Semiconductor Innovation (Moore Versus "More Than Moore")

Domain / market independent
Inventory 50+ Design Solutions

SCALING
Conventional
Equivalent
Diversified

Domain / market dependent
(Consumer) driver architecture



ITRS Design TWG 2007

Moore+ Parameter Inventory

Classification of 50+ design technology solutions

1. **Supporting Moore's Law –** More Moore **(geo scaling)**
2. **Extending Moore's Law –** More Moore **(equivalent scaling)**
3. **Beyond Moore's Law –** More Than Moore **(architecture diversification)**

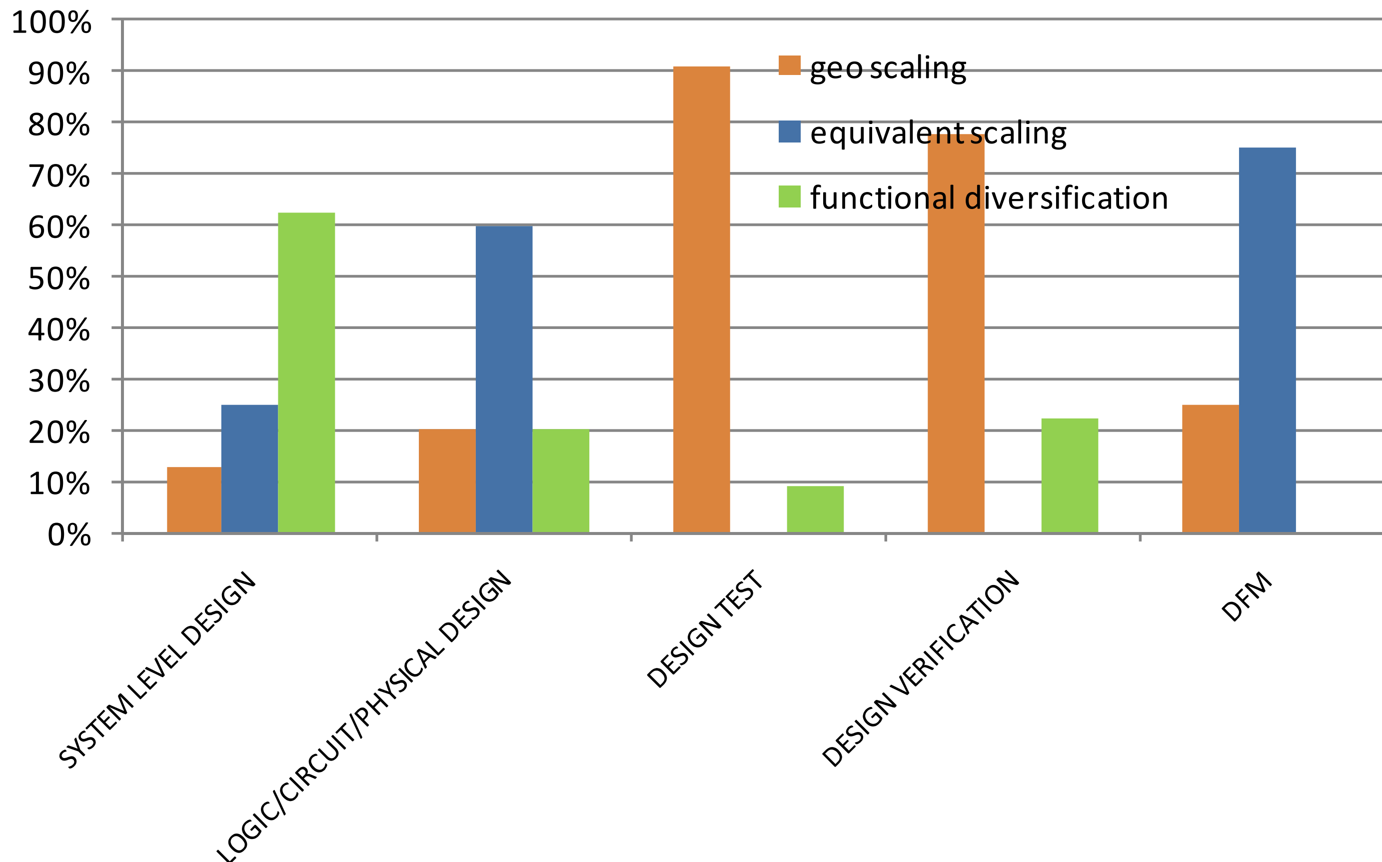
Example: System-Level Design Solutions

	Geometrical scaling	Equivalent scaling	Functional diversification
	Moore	More Moore	More Than Moore
System level component reuse	1		
Chip package co design methods			1
Improved system level power estimation techniques		1	
On chip network design methods	1		
mixed signal / RF verification		1	
automated interface synthesis			1
HW/SW co design and verification			1
Multi fabric implementation planning (AMS/RF/MEMS)			1

Design-Driven Semiconductor Innovation (Moore+)

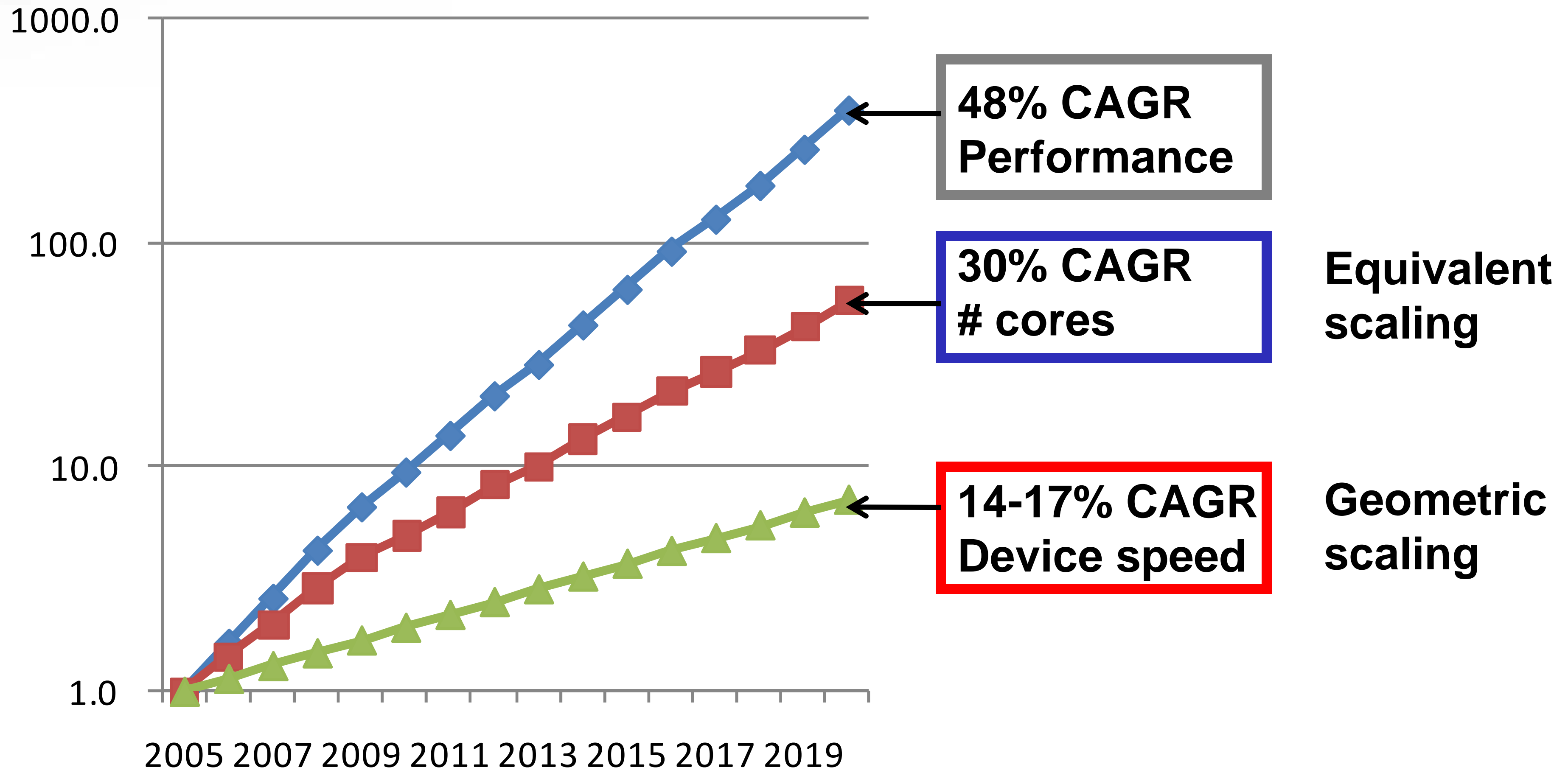
Domain / market independent *Inventory 50+ Design Solutions*

→ Reveals impact of More Than Moore on key design phases



More Than Moore "*Pilot Example*"

Focused on design levers e.g. multi-core



The New Scaling of Silicon Systems

Direct Alignment between iNEMI and ITRS
→ Consumer Portable Pilot Study

Key iNEMI contact: **Susan Noe**

1st Alignment Between Chip and System Roadmaps

Consumer portable pilot, focused on power/energy

Parameter	COLOR	Metric	2005	2007	2009	2011	2017	Where in ITRS
Number of Voltages		#						only one (core logic)
Minimum Logic Family Voltage		Volts	2.5	2	1.8	1.5	0.8	consumer driver
Maximum Logic Family Voltage		Volts	5	3.3	2.85	2.2	1.8	consumer driver
Normal Logic Family Voltage		Volts	3.3	2.85	2.2	1.8	1.2	consumer driver
POWER								
Power		Type	u Polymer, m	u Polymer, ı	u Polymer, m	u Polymer, meth	u Polymer, n	NO?
Spec. energy		Wh/kg	150	175	200	300	400	NO?
Energy dens		Wh/liter	400	500	550	600	800	NO?
Specific power		W/kg	1000	2000	4000	5000	6000	NO?
Shelf life		years	3 years	3 years	4 years	5 years	8 years	NO?
Avg. standby power		Watts						consumer driver
Voltage (avg.)		Volts						consumer driver
Voltage (min.)		Volts						consumer driver
Current (avg.)		mA						consumer driver
Run Time Before Recharge		Hours						NO?
Min. and Max. Operating Temperature		Degrees C						NO?
Max Reflow Temp		Degrees C						NO?
THERMAL								
Use Ambient Operating Temperature Range		Deg C - Deg C	-10 to 50	-10 to 50	-10 to 50	-10 to 50	-10 to 50	NO?
Thermal Design Power (Hottest Chip)		Watts	30	40	45	50	60	consumer driver
Max Current per Device		Amps						consumer driver
Thermal Design Flux (Hottest Chip)		W/sq. cm						NO?
Cooling Method		Passive,Active, I	both	both	both	both	both	NO?
Number of Chips W/Some Heat Sink		# / Assy or Boar						NO?
Device Cooling Air Temperature (Inside the Box)		Deg C						NO?
Device Cooling Rail Temperature		Deg C						NO?
Chips W/ Power < 2W		# / Per Assembl						consumer driver
Chips W/ Power From 2 - 5 W		# / Per Assembl						consumer driver
Chipc W/ Power From 5 - 10 W		# / Per Assembl						consumer driver
Chips W/ Power > 10 W		# / Per Assembl						consumer driver
Module Power		W / sq. cm.						NO?

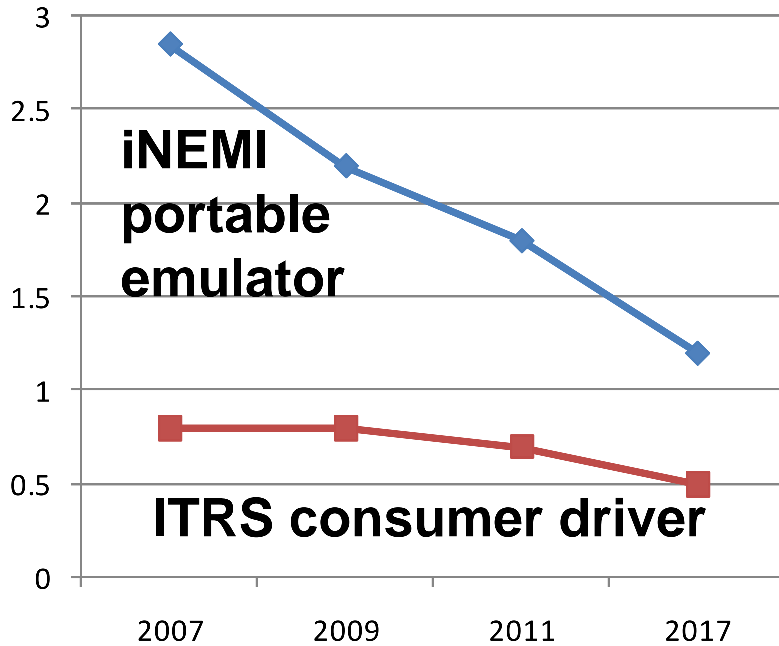
~10 parameters to be aligned

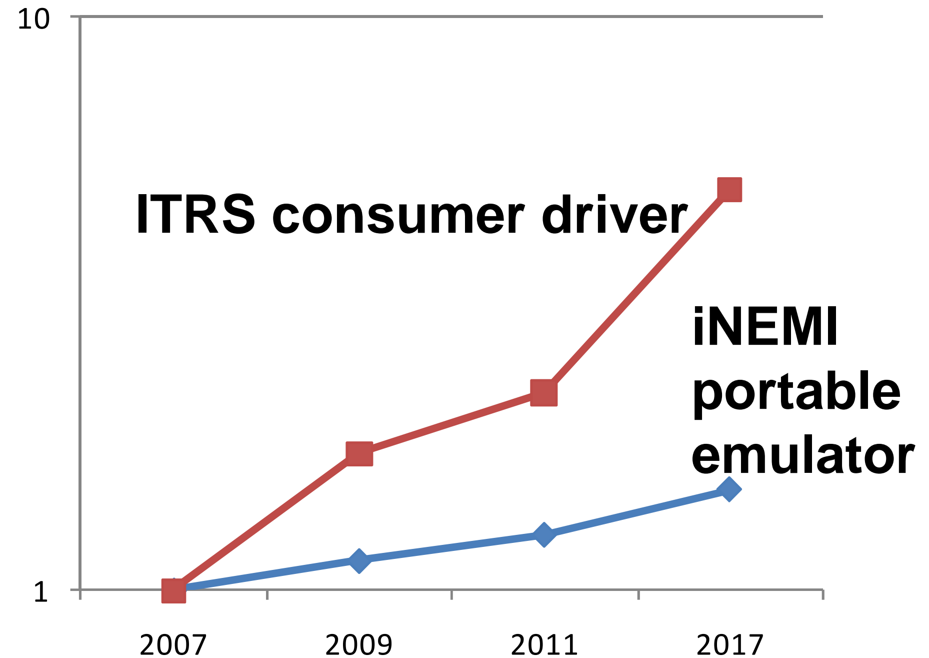
iNEMI-ITRS Power Reconciliation Top-10 Parameters to be Reconciled

Portable emulator						Consumer portable driver				
iNEMI	iNEMI	iNEMI	iNEMI	iNEMI	iNEMI		ITRS	ITRS	ITRS	ITRS
iNEMI Parameter	Metric	2007	2009	2011	2017	ITRS parameter	2007	2009	2011	2017
Normal Logic Family Voltage	Volts	2.85	2.2	1.8	1.2	Logic voltage	0.8	0.8	0.7	0.5
POWER										
Spec. energy	Wh/kg	175	200	300	400	N/A				
Avg. standby power	Watts					Total static power	0.052	0.09	0.146	0.58
Run Time Before Recharge	Hours	0.0875	0.05	0.06	0.06667	N/A				
THERMAL										
Use Ambient Operating Temp Range	Deg C - De	-10 to 50	-10 to 50	-10 to 50	-10 to 50	N/A				
Thermal Design Power (Hottest Chip)	Watts	40	45	50	60	total power	0.74	1.281	1.639	3.709
Max Current per Device	Amps					Chip current (P/V)	0.93	1.60	2.34	7.42
Thermal Design Flux (Hottest Chip)	W/sq. cm					N/A				
Cooling Method	Passive,Ac	both	both	both	both	N/A				

iNEMI VS ITRS (System V. Chip) Power Parameters' Comparison

ITRS stuck between lower voltages and higher power trends





Future iNEMI-ITRS
ITRS Portable *System* Model

Application processor	Baseband processor	Other (MEMS, etc.)
Memory NAND Flash	Memory Wireless Flash	
Audio / video codec	Power mgt.	
I/O controller	I/O transceivers	

→ **Processing**
POWER

→ **Memory / Flash**
COST

→ **Analog / I/O**
NOISE SENSITIVITY

Current Relevant Activities: Inclusion of New “Fabrics”: *Software*

NRE cost for SW design to equal HW design

→ *until design technology for SW issues is addressed*

SW cost

HW cost

	07	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SW	.0	39.1	29.6	40.7	56.4	79.0	33.6	46.7	31.1	42.5	27.2	35.2	34.0	46.6
HW	.5	22.5	15.7	20.3	19.4	26.3	32.9	44.9	29.5	39.8	25.2	32.6	27.0	36.9

ineering Costs + EDA Tool Costs

Total SW Engineering Costs + ESDA Tool Costs

Summary

1. **ITRS Design Group focuses on roadmapping:**
   1. **Design Chapter:** Technology challenges and solutions
   2. **System Drivers Chapter:** Types of silicon systems

2. **ITRS addressing new systems scaling**

   Conventional **(**Moore) + Heterogeneous (Moore+) scaling

3. **ITRS being aligned by market/application driver**

   "Fabric" drivers – market independent

   CPU, DSP/SPU, memory, AMS

   With iNEMI!

   "Market" drivers – market dependent

   consumer mobile and stationary, networking, office

Email contacts:

Chuck Richardson

chuck.richardson@inemi.org

Bob Pfahl

bob.pfahl@inemi.org