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Night view of the Knowledge Centre at Masdar City

Smart Power: An Energy System Transformation from Chip to Grid

IEEE Technology Time Machine: Symposium on Technologies Beyond 2020

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Professor of Practice

What is Smart Power?

"Doing More, Using Less"

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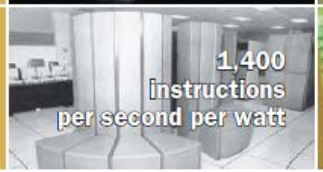
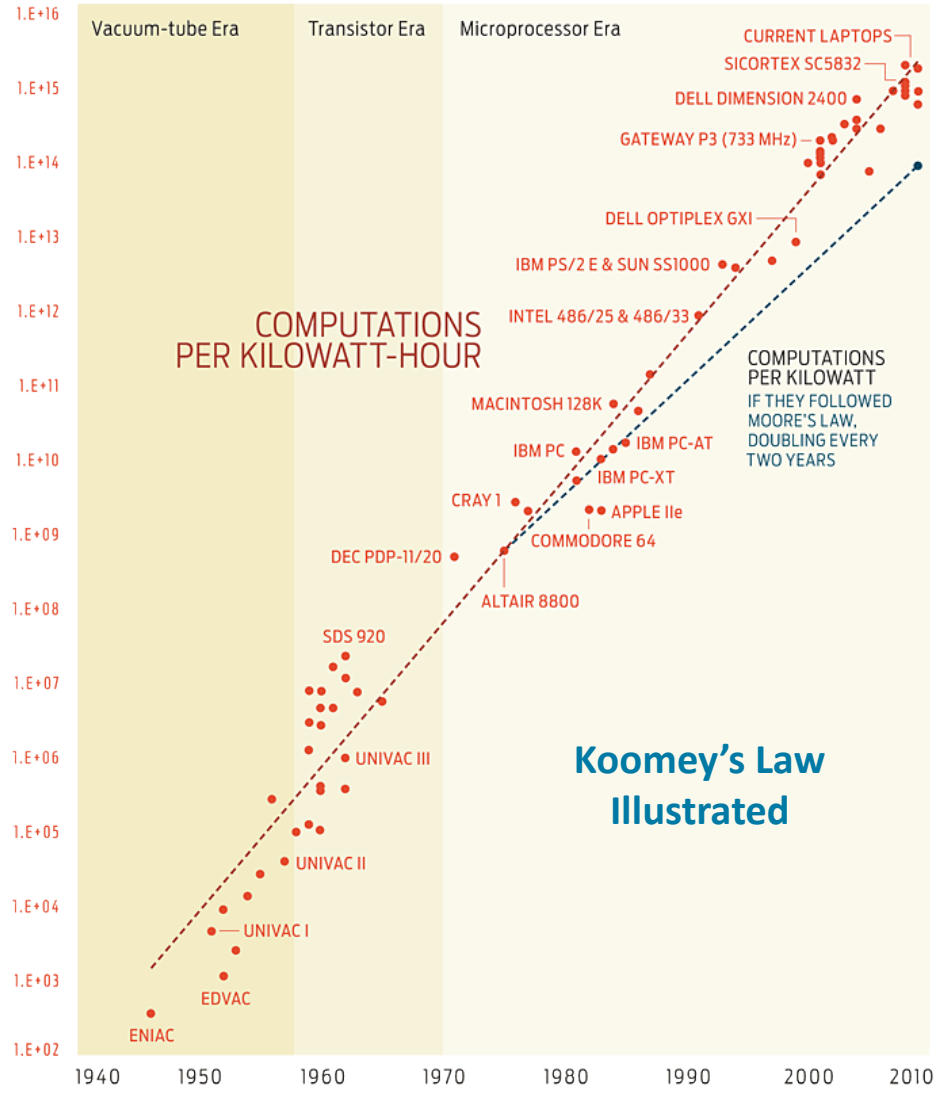
	1978	2008	Energy-efficiency improvement
Automobiles	 14.3 miles per gallon of gas	 20.0 miles per gallon of gas	40 percent
Passenger Airliners	 22.8 revenue passenger miles per gallon	 50.4 revenue passenger miles per gallon	121 percent
Agriculture	 0.63 units of output per unit of energy use	 1.46 units of output per unit of energy use	132 percent
Steel Manufacturing	 63 pounds of steel per MBtu	 167 pounds of steel per MBtu	167 percent
Lighting	 Incandescent light bulb— 13 lumens per watt	 Compact fluorescent bulb— 57 lumens per watt	339 percent
Computer Systems	 1,400 instructions per second per watt	 40,000,000 instructions per second per watt	2,857,000 percent

- **Smart use of power** is <u>not</u> simply energy conservation
- **Smart use of power** <u>is</u>
  - Efficient use of energy
  - Enhanced capabilities with low energy consumption

Source: Technology CEO Council, 2008: *A Smarter Shade of Green*

Evolution of Smart Power in Microelectronics

Increased performance with increased efficiency



- **Koomey's Law (2009):** the amount of power required for a fixed computing load falls by a factor of two every 18 months
- We've come a long way **but**
  - Current trends in energy electronics applications suggest that we'll need to continue to increase performance and efficiency in parallel for a long time to come…

Source: IEEE Specturm, 2010: *Outperforming Moore's Law*

Smart Power is an Energy System Transformation

"From Chip to Grid"

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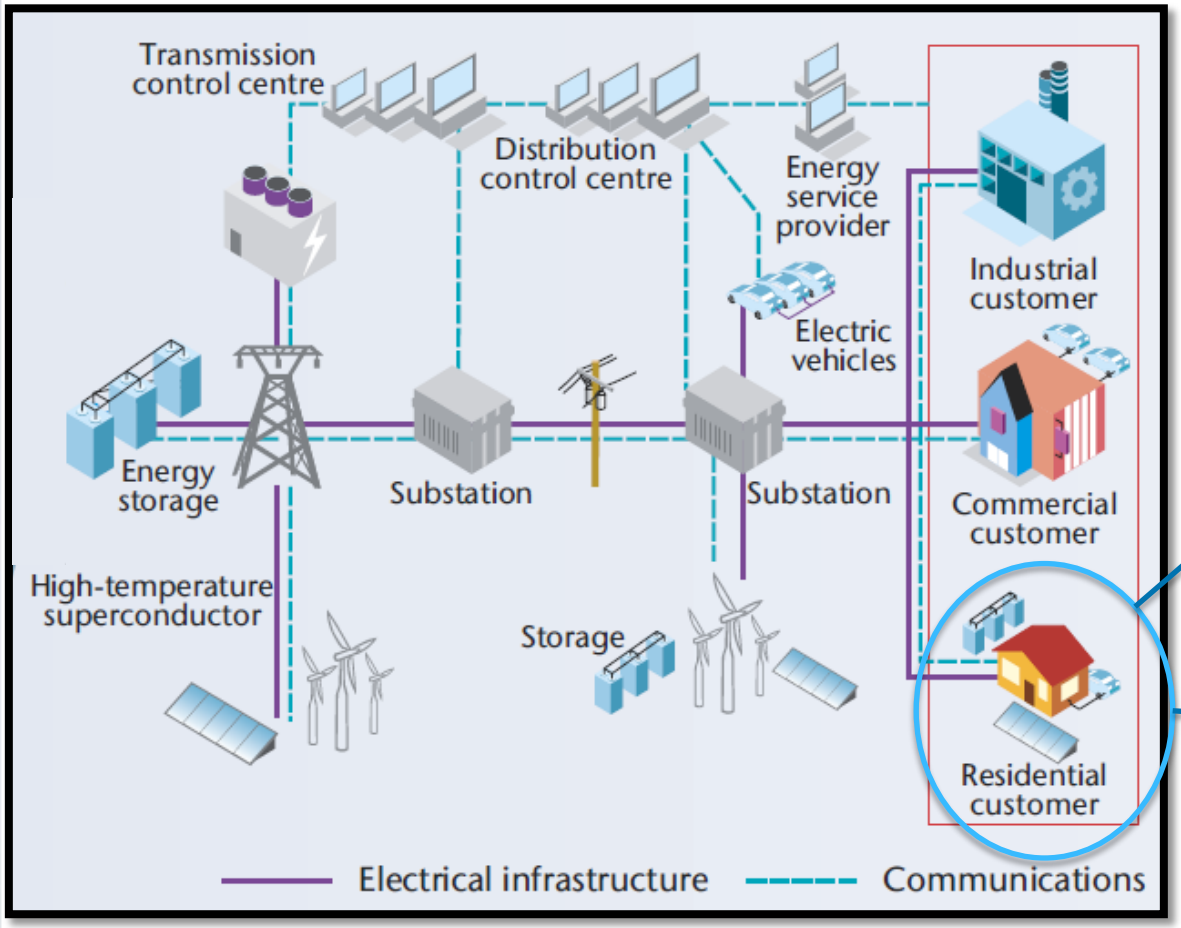
Supply
"Smart Grids"

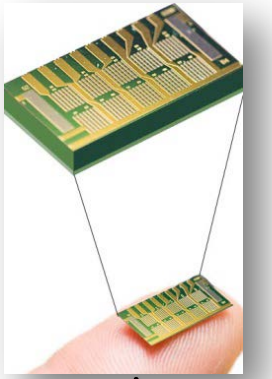


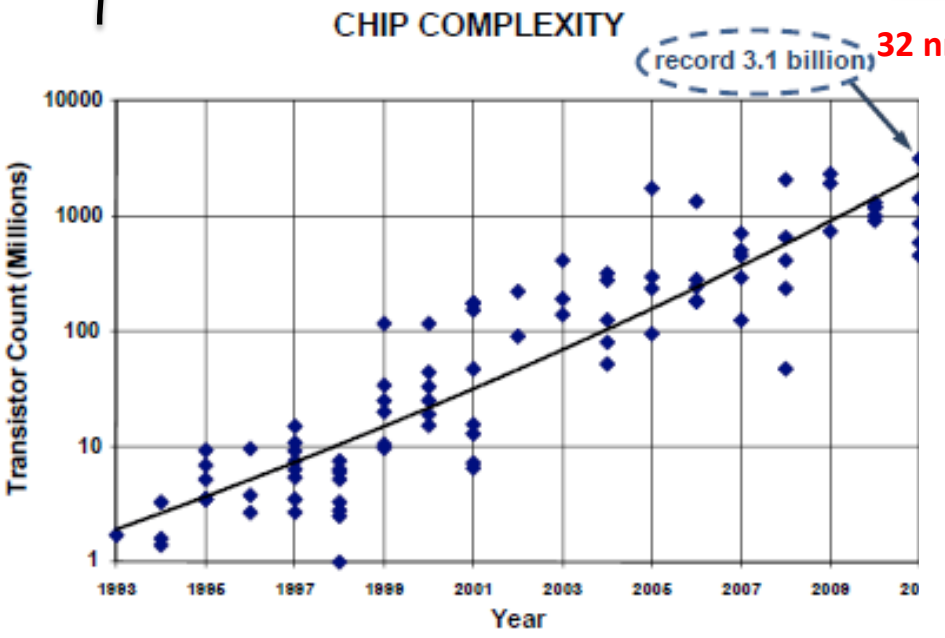
Source: IEA, 2011: *Smart Grids Technology Roadmap*

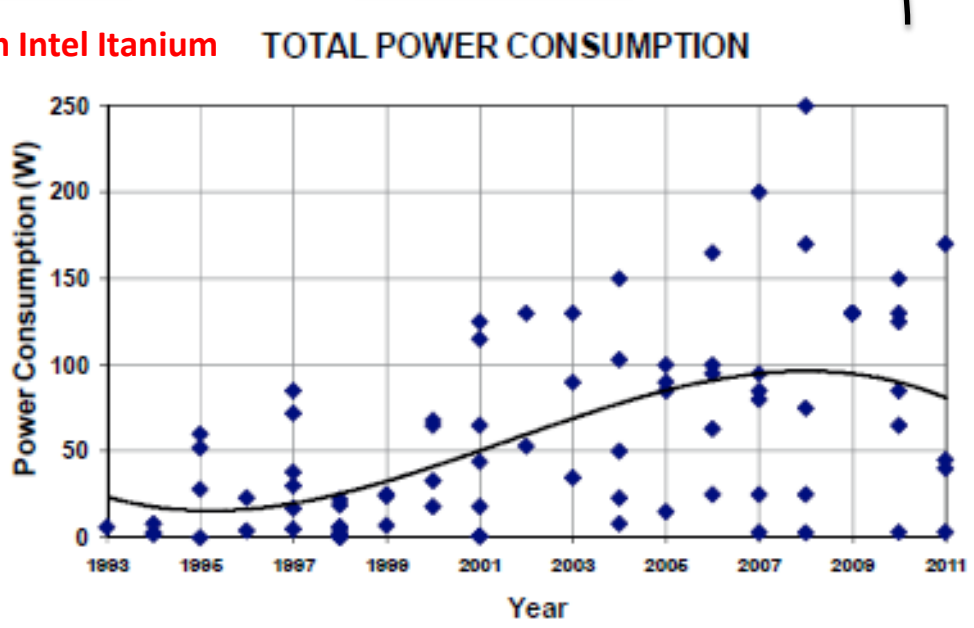
Demand
"Smart Homes" & "Prosumers"

Smart Power at the Chip and Device Level

Historical evolution of performance and efficiency



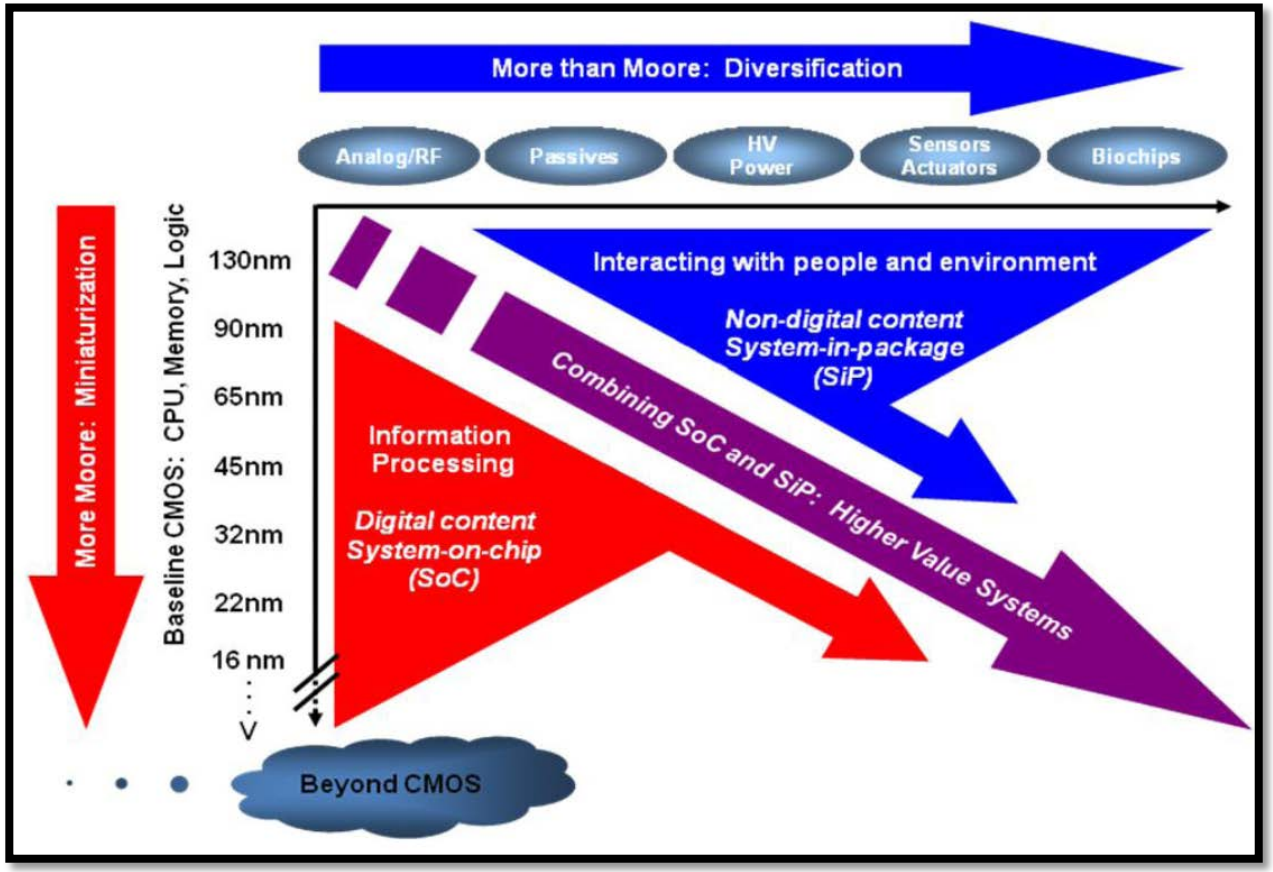




Source: ISSCC, 2011: *ISSCC 2011 TRENDS REPORT*

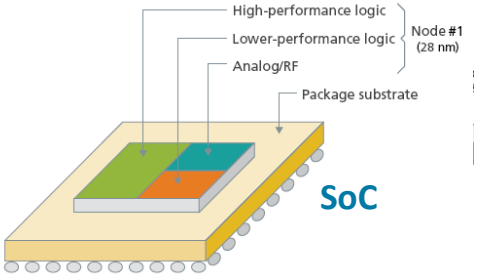
Smart Power at the Chip and Device Level

Future evolution of performance and efficiency

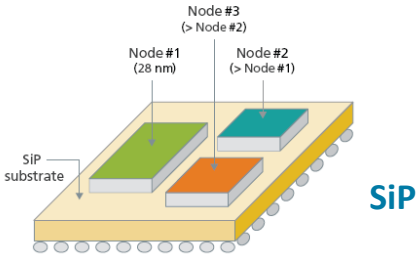


International Technology Roadmap for Semiconductors 2011

- **Scaling (MM)**
  - Geometric
  - Equivalent
  - Design Equivalent



- **Functional Diversification (MtM)**

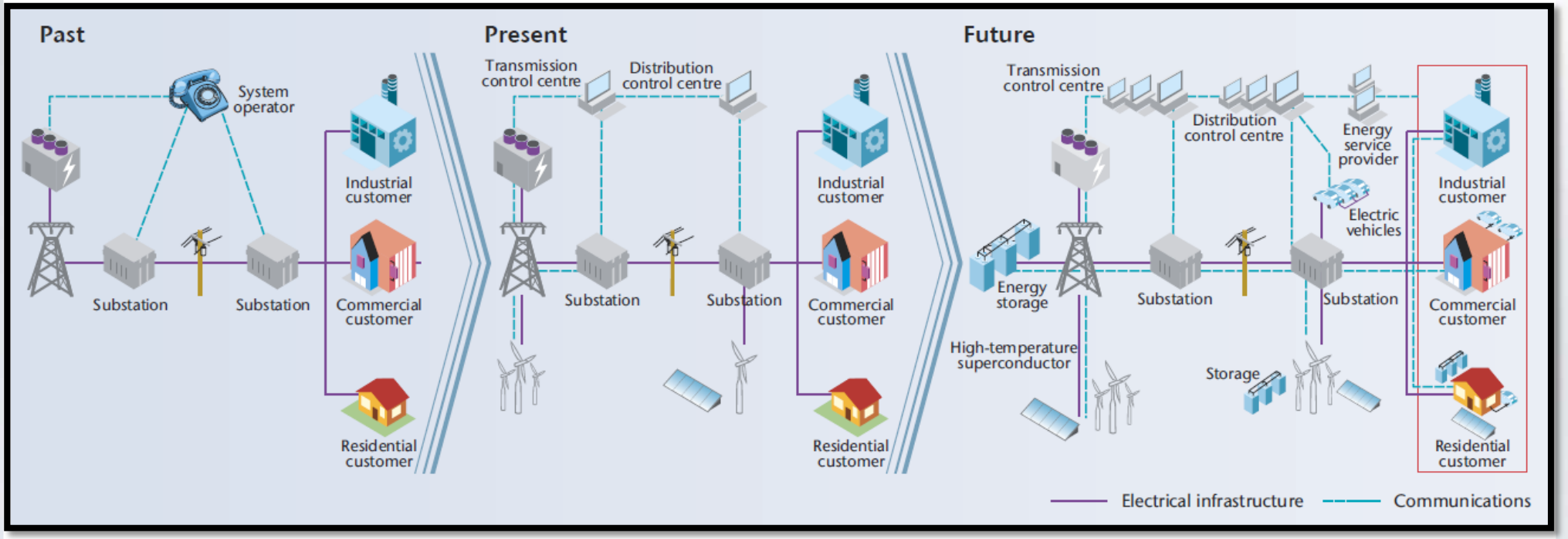


Cadence, 2011: *3D ICs with TSVs – Design Challenges and Requirements*

"Whereas "More Moore" may be viewed as the brain of an intelligent compact system, "More-than-Moore" refers to the system's capabilities to interact with the outside world."

Smart Power at Grid Scale

A responsive and adaptable system



Source: IEA, 2011: *Smart Grids Technology Roadmap*

Our Future Energy System will have an electrical grid that is

- Compatible with *"More-than-Moore"* devices
  - Enable energy conservation, efficiency and demand response
- Able to integrate significant levels of distributed, intermittent energy sources
- Architected for ultra-efficient, integrated flow of *information and electricity*

Smart Power at Grid Scale

Efficiency in delivery and use

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A Smart and Efficient Power Supply Chain

Generation

- Solar power
- Wind power
- Fuel cells

Distribution

- FACTS & SVC
- HVDC Transmission

Consumption

Industry

Consumer

Potential savings everywhere

- Traction (trains)
- Speed controlled motors
- Pumps
- Computer & server power supply
- Lighting
- TV, DVD, etc. supply & stand-by
- Inductive cooking
- Automotive

The "Power of Power Electronics"

2010: 30% of all electric power flows through power electronics

2030: 80% of all electric power flows through power electronics

- ARPA-E, 2010

POWER SUPPLY	LIGHTING	INDUCTIVE COOKING	TRACTION DRIVES	MOTOR CONTROL	AIR CONDITIONER	STAND-BY POWER (TV)
1% Saving potential	25% Saving potential	25% Saving potential	20-30% Saving potential	30-40% Saving potential	30-40% Saving potential	90% Saving potential
	(by Electronic ballast)	(using induction instead of electric ovens)	(using power semiconductors e.g. recuperation of braking energy)	(using inverters)	(using Intelligent Compressor Control)	

Source: Infineon, 2008: *Saving Energy with Advanced Power Semiconductors*

Smart Power

The driving force behind an efficient and connected planet

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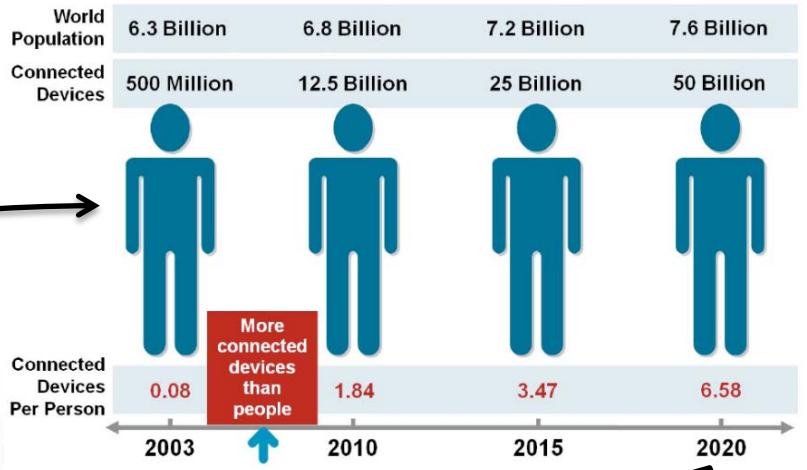
The Future of Business, Transport, Education, Energy, Healthcare,…

Individual networks, connected together, with security, analytics and management



6.56 connected devices per person by 2020

- Cisco, *The Internet of Things: How the Next Evolution of the Internet is Changing Everything*

Smart Power in Action

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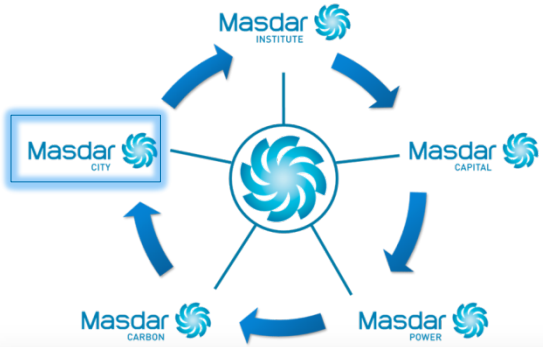
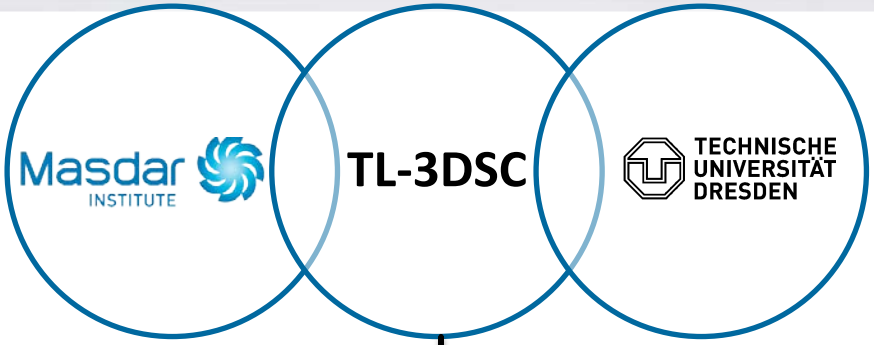


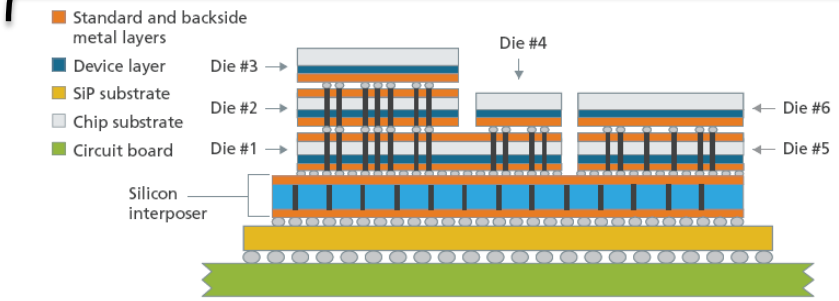
Masdar City – *The Future is Today*

- Designed with smart, energy and water efficient buildings
- Built with low-carbon materials
- Supplied by clean energy
- Powered by a smart grid

Smart Power Research at Masdar Institute

Twinlab 3D Stacked Chips (TL-3DSC) Research Center





Cadence, 2011: 3D ICs with TSVs – Design Challenges and Requirements

Enabling heterogeneous computing can largely reduce energy costs of computing, while making it more powerful and dependable

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- 3D-Integrated microelectronics for minimum energy design

TU-Dresden

- 3D Chip Stack interconnects for energy/bandwith optimization

Opportunities

- Integrate heterogeneous chips in the same vertical stack
- Very high-levels of integration, resulting in very-small form factors
- High data-rate systems that overcome bandwidth & area bottlenecks
- MEES: up to 90% savings in energy

THANK YOU