ESH and ITRS Impact on Semiconductor Technology Development

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Acknowledgments

- Jim Jewett – Intel – ESH TWG Chair
- Walter Worth – ISMI – ESH TWG Co-chair
- Members of the ESH TWG

Impacts of ESH Issues on the Industry

- **In the past, ESH issues have negatively impacted semiconductor manufacturers - Ethylene glycol ethers, CFCs, PFCs, PFOS**
  - Chemical exposure concerns (and lawsuits)
  - Environmental clean ups (Superfund Sites)
  - Use restriction regulations

Designing for Sustainability allows for early identification of potential ESH issues

- **Resolve issues before process transfer to high volume manufacturing**

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What is Sustainable Development?

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Source: Brundtland Commission, 1987

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Why Sustainability Now?

- **Semiconductor industry is international.**
  - **Sites in many regions of the world.**
  - **Customers in many regions of the world.**
- **Increased environmental awareness resulting in increased focus on corporate sustainability & responsibility.**
  - **Company-driven**
  - **NGOs**
  - **Shareholders**
- **While U.S. environmental regulations have changed little in recent years, same is not true of other regions.**
- **Technologists must ensure products and processes they develop are sustainable.**

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EU Sustainable Development Strategy Priority Challenges

- **Climate change and clean energy.**
- **Sustainable transport.**
- **Sustainable production and consumption.**
- **Public health threats.**
- **Better management of natural resources.**
- **Social inclusion, demography, and migration.**
- **Fighting global poverty.**

2007 ESH TWG Participants

- James Beasley – ISMI
- Laurie Beu – Laurie S. Beu Consulting
- Aimee Bordeaux - SEMI
- Reed Content – AMD
- Tom Diamond - IBM
- **Hans Peter Bipp – Infineon***
- John Harland – Intel
- Shane Harte - ESIA
- David Harman – Intel
- Bob Helms – University of Texas
- Stan Hughes – Applied Materials
- Shigehito Ibuka – TEL
- **Francesca Illuzi – ST Microelectronics***
- **Jim Jewett – Intel***
- Bruce Klafter – Applied Materials
- **Joey Lu – TSIA***
- Joseph K.C. Mau – Powerchip Semiconductor
- Ed McCarthy - Freescale Semiconductor
- Laura Mendicino - Freescale Semiconductor
- Mike Mocella - DuPont
- Phil Naughton – ISMI
- **Takayuki Ohgoshi – NEC Electronics***
- Brian Raley - AMD
- Farhang Shadman – U of AZ
- Mike Sherman – FSI International
- Jeffrey Sczechowski – ST Microelectronics
- Harry Thewissen – NXP Semiconductors
- **Tetsu Tomine – Seiko-Epson***
- Tim Wooldridge - SRC
- **Walter Worth – Sematech***
- Munetsugu Yamanaka – TEL
- Tim Yeakley – Texas Instruments

*** = ITWG Members**

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ESH Key Themes for 2007

- Focus on critical chemistry/materials needs
- Improvement of energy efficiency
- “ECO” design of factories and products

Underlying Strategies Built into 2007 ESH Chapter

- **Understand (characterize) processes and materials to create a development baseline**
- **Use materials that are less hazardous or whose byproducts are less hazardous**
- **Design products and systems (equipment and facilities) that consume less raw material and resources**
- **Ensure factories are safe for employees (300mm to 450mm transition)**

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Reorganized Tables

- Chemical/Materials Tables focus on chemical selection
- Process Tables focus on process and tool design
- Facilities Tables (new) focus on support systems and fab level design
- Design for Sustainability & Product Stewardship Table focuses on metrics and sustainable product design and manufacture

Difficult Challenges – Chemicals & Materials Management

Table ESH1a ESH Difficu

Difficult Challenges ≥ 22 nm	*Summary of Issues*
Chemicals and materials management	*Chemical Asses*
	Evalu nanomaterials can be utilize environment without delayi
	Regional differences in regulatio and full commercialization
	Trend towards lowering exposur
	Chemical Data Availability
	Inability to forecast/anticipate fu
	Lack of comprehensive ESH data for new, proprietary chemicals and materials to respond to the increasing external and regional requirements on the use of chemicals
	Chemical Exposure Management
	Lack of information on how the chemicals and materials are used and what process by-products are formed
	Method to obtain information on how the chemicals and materials are used and what process by-products are formed

Evaluation and refinement of quality, rapid assessment methodologies to ensure that new materials such as nanomaterials can be utilized in manufacturing, while protecting human health, safety and the environment…

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Difficult Challenges – Chemicals & Materials Management

Table ESH1a ESH Difficult Challenges—Near-term

Difficult Challenges ≥ 22 nm	*Summary of Issues*
Chemicals and materials management	*Chemical Assessment*
	Evaluation and refinement of quality, rapid assessment methodologies to ensure that new materials such as nanomaterials can be util… environment without dela…
	Regional differences in regula… …ring, and full commercializatio…
	Trend towards lowering expos…
	Chemical Data Availability
	Inability to forecast/anticipate…
	Lack of… …easing external and…
	Chemical Exposure Managem…
	Lack of information on how th… …ormed
	Method to obtain information on how the chemicals and materials are used and what process by-products are formed

Lack of comprehensive ESH data for new, proprietary chemicals and materials to respond to the increasing external and regional requirements on the use of chemicals

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Difficult Challenges – Process & Equipment Management

Process and equipment management	*Process Chemical Optimization*
	Need to develop equipment and processes that meet technology demands while reducing impact on human health, safety and the environm chemical q requirements
	Environment Mana
	Capability for compone Need to understand ESH c mitigation Need to develop effective manage residues from the manufacturin
	Global Warming Emissions Reducti
	Need to reduce emissions from proc
	Water and Energy Conservation
	Need for innovative energy- and wa
	Consumables Optimization
	Need for more efficient utilization o
	Byproducts Management
	Development of improved metrolog

Need to develop equipment and processes that meet technology demands while reducing impact on human health, safety, and the environment, both by using more benign materials and by reducing chemical quantity requirements through more efficient and cost-effective process management

Difficult Challenges – Process & Equipment Management

	Process Chemical Optimization
	Need to develop equipment and processes that meet technology demands while reducing impact on human health, safety and the environment, both through the use of more benign materials, and by reducing chemical quantity requirements through more efficient and cost-effective process management
	Environment Management
	Capability for component isolation in waste streams Need to understand ESH characteristics of process emissions and by-products to identify the appropriate mitigation Need to develop effective management systems to address issues related to hazardous and non-hazardous residues from the manufacturing processes
	Global Warming Emissions Reduction
	Need to reduce emissions from processes using high GWP chemicals
	Water and Energy Conservation
	Need for innovative energy- and water-efficient processes and equipment
Process and equipment management	*Con ... Optimization*
	... of chemicals and materials, and increased reuse and recycling
	...gy for byproduct speciation.

Need for innovative energy- and water-efficient processes and equipment

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Difficult Challenges – Facilities technology requirements and Sustainability and product stewardship

Facilities technology requirements	*Conservation*
	Need to reduce use of Need for m
	Global Warming Emis
	Need to design energy Need to reduce total CO_2 equivalent emissions
Sustainability and product stewardship	*Sustainability Metrics*
	Need to identify the elements for defining and measuring the sustainability of a technology generation
	Design for ESH
	Need to make ESH a design parameter at the design stage of new equipment, processes and products
	End-of-Life Disposal/Reclaim
	Need to design facilities, equipment and products to facilitate re-use/disposal at end of life

Need to reduce use of energy, water, and other utilities.
Need for more efficient thermal management of cleanrooms and facilities systems

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Difficult Challenges – Facilities technology requirements and Sustainability and product stewardship

Facilities technology requirements	*Conservation*
	Need to reduce use of energy, water and other utilities Need for more efficient thermal management of cleanrooms and facilities systems
	Global Warming Emissions Reduction
	Need to design energy efficient manu… Need to reduce total CO_2 equivalent e…
Sustainability and product stewardship	*Sustainability Metrics*
	Need to identify the elements for defin… …on
	Design for ESH
	Need to make ESH a design param… …ts
	End-of-Life Disposal/Reclaim
	Need to design facilities, equipment and products to facilitate re-use/disposal at end of life

Need to identify the elements for defining and measuring the sustainability of a technology generation

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Difficult Challenges – Facilities technology requirements and Sustainability and product stewardship

Facilities technology requirements	*Conservation*
	Need to reduce use of energy, water and other utilities Need for more efficient thermal management of cleanrooms and facilities systems
	Global Warming Emissions Reduction
	Need to design energy efficient manufacturing facilities Need to reduce total CO_2 equivalent emiss
Sustainability and product stewardship	*Sustainability Metrics*
	Need to identify the elements for defining
	Design for ESH
	Need to ma
	End-of-Life Disposal/Reclaim
	Need to design facilities, equipment and p

Need to make ESH a design parameter at the design stage of new equipment, processes, and products

ESH Intrinsic Requirements

Table ESH2a ESH Intrinsic Requirements—Near-term Years

Year of Production	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
I. Chemicals and Materials Management Technology Requirements									
Chemical risk assessments (environmental, health and safety) defined and completed	100%		100%		100%				
ESH risk assessment techniques for nano-materials and nano-particles	Develop assessment methodology.		Implement risk assessment methodology.						
II. Process and Equipment Technology Requirements									
Energy Consumption									
Total fab tools (kWh/cm^2) [2]	0.40–0.35			0.35-0.30			0.30-0.25		
Tool energy usage (% of 2005 baseline)	90			80			Functional Area Goals TBD		
Tool total equivalent energy* (% of 2007 baseline)	100		80	70			60		
Water Consumption (driven by sustainable growth and cost)									
Surface preparation UPW use (% of 2005 baseline)	90			80			75		
Tool UPW usage (% of 2005 baseline)	90			80			75		
Chemical Consumption and Waste Reduction (driven by environmental stewardship and cost)									
Improvement in process chemical utilization (% of 2005 baseline)	90			80			75		
Reduce PFC emission	10% absolute reduction from 1995 baseline by 2010 as agreed to by the World Semiconductor Council (WSC)				Maintain 10% absolute reduction from 1995 baseline				
Liquid and solid waste reduction (% of 2007 baseline)	100		90	80			75		

Manufacturable solutions exist, and are being optimized	(white)
Manufacturable solutions are known	(yellow)
Interim solutions are known	(striped)
Manufacturable solutions are NOT known	(red)

ESH Intrinsic Requirements

Worker and Workplace Protection					
Safety screening methodologies for new technologies (e.g., 450mm, EUV lithography, ERM)	**Develop methodologies.**			**Implement methodologies.**	
III. Facilities Technology Requirements					
Energy Consumption					
Total fab energy usage (kWh/cm^2)	**1.5-1.3**			**1.3-1.1**	**1.1-1.0**
Total fab support systems energy usage (kWh/cm^2) [2]	**0.8–0.6**			**0.6–0.5**	**0.5-0.4**
Reduce total fab energy usage (% of 2007 baseline)	**100**		**90**	**80**	**70**
Water Consumption					
Net feed water use (liters/cm^2) [2]	**15**	**15-12**		**12-10**	**10-8**
Fab UPW use (liters/cm^2) [2]	**8**	**8-7**		**7-6**	**6-4**
Chemical Consumption and Waste Reduction					
Reduce hazardous liquid waste by recycle/reuse** (% of 2007 baseline)	**100**		**90**	**80**	**75**
Reduce solid waste by recycle/reuse** (% of 2007 baseline)	**100**		**90**	**80**	**75**
IV. Sustainability and Product Stewardship Requirements					
Define environmental footprint metrics for process, equipment, facilities, and products; reduce from baseline year.	**Define metrics and baseline.**			**90% of baseline**	**80% of baseline**
Integrate ESH priorities into the design process for new processes, equipment, facilities, and products.	**Define metrics and baseline.**				
Facilitate end-of-life disposal/reclaim	**Define metrics and baseline.**				

Technology Requirements Tables

- Tables for “Chemicals” and “Processes and Equipment” provide requirements for technology thrusts
  - Interconnect
  - Front End Processing
  - Lithography
  - Assembly & Packaging
  - Emerging Research Materials
- Other tables focus on “Facilities” and “Sustainability”

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Chemicals and Materials Management Technology Requirements

Table ESH3a Chemicals and Materials Management Technology Requirements—Near-term Years

The Environment, Safety, and Health new chemical screening tool (Chemical Restrictions Table) is linked online

Characterize emissions; establish baseline

Year of Production	2007	2008	2009	2010	2011	2012	2013	2014	2015
Interconnect									
Surface preparation	Alternatives with improved ESH impacts. Maintain or improve chemical utilization* … characteri… emissions…	Alternatives with improved ESH impacts. Maintain …		Alternatives with improved ESH impacts. Maintain or …hemical … by 10%.			Alternatives with improved ESH impacts. Maintain or improve chemical utilization* by 10%.		
Front End Processes									
High-κ and metal gate materials	Conduct E… Maintain … minimize …			…r improve …tilization* by …minimize process …s			Maintain or improve chemical utilization* by 10% and minimize process byproducts		
Doping (implantation and diffusion)	Low ha… …opant materials			Low hazard dopant materials					
Conventional surface preparation (stripping, cleaning, rinsing, drying)	Characteri… emissions; establish baseline.	Maintain or improve chemical usage by 10%.		Maintain or improve chemical usage by 10%.			Maintain or improve chemical usage by 10%.		
Alternative surface preparation methods	Identify novel wafer cleaning materials. Conduct ESH risk assessment of materials			Maintain or improve chemical usage by 10% and minimize process byproducts			Maintain or improve chemical usage by 10% and minimize process byproducts		

Manufacturable solutions exist, and are being optimized (white)

Manufacturable solutions are known (yellow)

Interim solutions are known (striped with red diamond)

Manufacturable solutions are NOT known (red)

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Chemicals and Materials Management Technology Requirements

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Year of Production	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Interconnect									
Surface preparation	Alternatives with improved ESH impacts. Maintain or improve chemical utilization*; characterize emissions.	Alternatives with improved ESH impacts. Maintain or improve		Alternatives with improved ESH impacts. Maintain or improve chemical … 10%.			Alternatives with improved ESH impacts. Maintain or improve chemical utilization* by 10%.		
Front End Processes									
High-κ and metal gate materials	Conduct ES… Maintain or i… minimize pr…			…mprove …zation* by …imize process			Maintain or improve chemical utilization* by 10% and minimize process byproducts		
Doping (implantation and diffusion)	Low…			Low hazard dopant materials					
Conventional surface preparation (stripping, cleaning, rinsing, drying)	Characterize… emissions; e… baseline.	…sage by 10%.		…mprove …ge by 10%.			Maintain or improve chemical usage by 10%.		
Alternative surface preparation methods	Identify novel wafer cleaning materials. Conduct ESH risk assessment of materials			Maintain or improve chemical usage by 10% and minimize process byproducts			Maintain or improve chemical usage by 10% and minimize process byproducts		

Identify new wafer cleaning materials. Conduct ESH assessment of materials

Manufacturable solutions exist, and are being optimized (white)

Manufacturable solutions are known (yellow)

Interim solutions are known (striped)

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Chemicals and Materials Management Technology Requirements

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Year of Production	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Interconnect									
Surface preparation	Alternatives with improved ESH impacts. Maintain or improve chemical utilization*; characterize emissions.	Alternatives with improved ESH impacts. Maintain or improve chemical utilization* by 10%.		Alternatives with improved ESH impacts. Maintain or improve chemical utilization* by 10%.			Alternatives with improved ESH impacts. Maintain or improve chemical utilization* by 10%.		
Front End Processes									
High-κ and metal gate materials	Conduct ESH risk assessment of materials. Maintain or improve chemical utilization*; minimize process byproducts			Maintain or improve chemical utilization* by 10% and minimize process byproducts			Maintain or improve chemical utilization* by 10% and minimize process		
Doping (implantation and diffusion)	Low hazard dopant materials			Lo					
Conventional surface preparation (stripping, cleaning, rinsing, drying)	Characterize emissions; establish baseline.	Maintain or improve chemical usage by 10%.		Maintain or impr chemical usag					
Alternative surface preparation methods	Identify novel wafer cleaning materials. Conduct ESH risk assessment of materials			Maintain chemical usage by 10% and minimize process byproducts			chemical usage by 10% and minimize process byproducts		

Maintain or improve chemical and water utilization by 10%

Manufacturable solutions exist, and are being optimized	White
Manufacturable solutions are known	Yellow
Interim solutions are known	Yellow/orange striped with red diamond
Manufacturable solutions are NOT known	Red

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Chemicals and Materials Management Technology Requirements

Year of Production	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Lithography									
193 nm immersion resists	Conduct ESH risk assessment of materials.			Maintain or improve chemical utilization* by 10%.			Maintain or improve chemical utilization* by 10%.		
193 nm immersion fluids	Conduct ESH risk assessment of materials.	Maintain or improve chemical utilization by 10%.		Maintain or improve chemical utilization* by 10%.			Maintain or improve chemical utilization* by 10%.		
EUV resists	Conduct ESH risk assessment of materials.			Maintain or improve chemical utilization* by 10%.			Maintain or improve chemical utilization* by 10%.		
Imprint	Conduct ESH risk assessment of materials.			Conduct ESH risk assessment of materials.			Maintain or improve chemical utilization* by 10%.		
PFOS/PFAS** chemicals	PFOS/PFAS alternatives researched / implemented						Non-PFAS materials developed for critical uses in lithography		
Mask making and cleaning	Characterize emissions; establish baseline.	Alternatives with improved ESH impacts. Maintain or improve chemical utilization by 10%; minimize process byproducts.		Alternatives with improved ESH impacts. Low ESH impact chemistries Maintain or improve chemical utilization* by 10%; minimize process byproducts.			Alternatives with improved ESH impacts (PFOS-free). Maintain or improve chemical utilization* by 10%; minimize process byproducts.		
Emerging Research Materials									
Nanomaterials	Conduct ESH risk assessment of materials.			Conduct ESH risk assessment of materials.					
Biological materials and their waste	Conduct ESH risk assessment of materials.			Conduct ESH risk assessment of materials.					
Materials for novel logic and memory	Conduct ESH risk assessment of materials.			Conduct ESH risk assessment					

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Chemical Restrictions Screen

Issues & Characterization	Show Stopper	High Restriction Potential	Medium Restriction Potential
List of chemicals or raw materials subject to actual or potential manufacture or use restrictions	**Asbestos materials** **Certain glycol ethers** **Polychlorinated biphenyls** **Fully halogenated chlorofluorocarbons (CFCs)** **Carbon tetrachloride** **1,1,1 trichloroethane** **Halons 1211, 1301, 2402** **Hydrobromofluorocarbons (HBFCs)** **HCFC 141b** **Polybrominated biphenyls (PBBs) and their ethers/oxides (PBDEs)** **Cadmium compounds** **Lead compounds** **Mercury compounds** **Hexavalent Chromium compounds** **Polychlorinated biphenyls (PCB)/ terphenyls (PCT)** **Polychlorinated naphthalene (PCN)** **Short chain chlorinated paraffins (C10-13, Cl >50%)** **Tributyl tin (TBT) and, triphenyl tin (TPT) compounds** **Certain azo colorants**	**Hydrochlorofluorocarbons (HCFCs)** **Perfluorooctyl sulfonates (PFOS)** **Cadmium compounds** **Lead compounds** **Mercury compounds** **Hexavalent chromium compounds**	**Perfluorocompounds (PFCs)** **- SF6 - C4F10** **- C2F6 - C5F12** **- CF4 - C6F14** **- NF3** **- C4F8** **- CHF3** **- C3F8** **Hydrofluorocarbons (HFCs)** **Perfluorooctanoic acid (PFOA) and its salts** **Certain phthalates** **Phenols** **Perfluoroalkyl sulfonates (PFAS)** **Ethylene oxide** **Ethylene chloride**

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http://www.itrs.net/models.html

Process and Equipment Technology Requirements

Table ESH4a Process and Equipment Management Technology Requirements—Near-term Years

** The Environment, Safety, and Health new chemical screening tool (Chemical Restrictions Table) is linked online*

Year of Production	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Interconnect									
Surface preparation	Establish baseline for chemical and water usage.; characterize emissions	> 15% Reduction in chemicals and water usage from baseline					Additional 2% reduction in chemicals and water usage per year; recycle/reclaim		
Front End Processes									
Surface preparation (stripping, cleaning, rinsing)	ESH-friendly wa… processes and …			…r clean and rinse processes and tools …manufacturing					
	Characterize emissions; establish water and chemical usage baselines			…ve chemical …ion* by 10%			Maintain or improve chemical and water utilization* by 10%		
	Energy efficient clean processes (reduced exhaust flow rates, optimized heaters)			Energy efficient clean processes (optimized exhaust flow rates, optimized heaters)					
Alternative surface preparation methods	Identify novel wafer cleaning processes and equipment. Characterize emissions; establish water and chemical usage baselines. Conduct ESH risk assessment			Novel wafer cleaning technologies evaluated and optimized to minimize ESH impact			Novel wafer cleaning technologies implemented		

Energy efficient cleans processes (reduced exhaust flow rates, optimized heaters)

Manufacturable solutions exist, and are being optimized

Manufacturable solutions are known

Interim solutions are known

Manufacturable solutions are NOT known

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Process and Equipment Technology Requirements

Table ESH4a Process and Equipm… …rm Years

** The Environment, Safety, and Health new chemical scree…*

Develop eco-design criteria, establish metrics and targets for minimized environmental footprint and impact.

Year of Production	*2007*		*2014*	*2015*
New Equipment Design				
Eco-design	Develop ec… metrics and ta… environmental footprint and impact.		…ent to minimize …d health impact	
Design for Maintenance	Develop safe maintenance criteria.	Design equipment so that commonly serviced components and consumable items are easily and safely accessed		
Energy Consumption (kWh per cm2) [1]	Characterize energy requirements for process and ancillary equipment.	C… ec…	…ary …5%	
Water and other utilities (liters or m3 / cm2) [1]	Characterize water and utilities requirements for process… consumption. Determine feas… water recycle/reclaim; reduce water and utilities requirements 15% per technology node		…5%	
Chemicals (gms/cm2) [1]	Conduct ESH risk assessment of processes and equipment.	C… M… en…	…nt. …ess …5%	
Consumables**	Establish consumables baseline.			
Equipment thermal management	Establish baseline	R… equipment to cleanroom air by 15% from baseline	…om equipment to cleanroom air by additional 15%	

Characterize water and utilities requirements for process. Optimize consumption. Determine feasibility for water recycle/reclaim; reduce water and utilities requirements 15% per technology node.

Manufacturable solutions exist, and are being optimized

Manufacturable solutions are known

Interim solutions are known

Manufacturable solutions are NOT known

Facilities, Energy & Water Technology Requirements

Develop facilities to minimize environmental footprint and impact.

Meet a recognized standard for reduced environmental impact through building re-use; e.g., LEED, etc.

Year of Production	*2007*	*2008*		*2014*	*2015*
Facilities Design					
Eco-friendly facility design	Design facilities to minimize environmental footprint and impact		Meet a recognized standard for designing and rating a reduced environmental [illegible]		
Design for end-of-life re-use	Comprehend and implement potential re-use scenarios during facility design		Me[illegible]	[illegible]g	
Water					
Total fab* water consumption (liters/cm²) [1]	14		[illegible]	[illegible]	
Total site water consumption reduction	Establish baseline	Reduce total consumption 10% from baseline levels	Reduce total consumption additional 10%	Reduce total consumption additional 10%	
Total UPW consumption (liters/cm²) [1]	8		7	6	
UPW recycled/reclaimed** (% of use)	70		75	80	
Energy (electricity, natural gas, etc.)					
Total fab* energy consumption (kWh per cm²) [1]	1.9		1.6	1.35	
Total site energy consumption reduction	Establish baseline	Reduce total consumption 10% from baseline levels	Reduce total consumption additional 10%	Reduce total consumption additional 10[illegible]	
Cleanroom thermal management	Establish baseline		Reduce heat rejection from process and ancillary equipment to cleanroom air by 15% from baseline	Reduce heat rejec[illegible] and ancillary equip[illegible] air by addit[illegible]	

Sustainability and Product Stewardship

Develop key environmental performance indicators (KEPIs) and establish baseline.

Year of Production	*2007 / 2008 / 2009*	*20*			*2019 / 2020 / 2021 / 2022*
Sustainability Metrics					
Facilities Eco-design	Develop eco-design criteria, establishing metrics and targets for minimized environmental footprint and impact				ental footprint, and safety and
Carbon footprint	Identify common metrics and establish baseline				
Product Eco-design	Develop key environmental performance indicators (KEPIs)* and establish baseline	Reduce KEPIs* 10% from baseline levels	Reduce KEPIs* additional 10%	Reduce KEPIs* additional 10%	Reduce KEPIs* additional 10%
Design for ESH					
Materials	Develop key environmental performance indicators (KEPIs)* and establish baseline	Reduce KEPIs* 10% from baseline levels	Reduce KEPIs* additional 10%	Reduce KEPIs* additional 10%	Reduce KEPIs* additional 10%
	Early assessment of ESH impacts during the very early stages of R&D (when materials are being compared and selected)				
Processes	Develop key environmental performance indicators (KEPIs)* and establish baseline	Reduce KEPIs* 10% from baseline levels	Reduce KEPIs* additional 10%	Reduce KEPIs* additional 10%	Reduce KEPIs* additional 10%
		Alternative low-ESH impact processes for planarization and deposition		Paradigm shift to additive processing	
	Early assessment of ESH impacts during the very early stages of R&D (when processes are being compared and selected)				
Improved integration of ESH into factory and equipment design	Incorporate ESH design guidelines, methodology, and criteria into tool and factory design, e.g., LEED**				
End-of-Life					
Ease of decommissioning and decontamination for facility re-use/re-claim	Comprehend and implement potential re-use scenarios during facility design	Reduce environmental impact through building design for re-use		Reduce environmental impact through building design for re-use	
Ease of decommissioning and decontamination for equipment re-use/re-claim	Design process and ancillary equipment for disassembly and re-use/reclaim				

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Potential Solutions

- Nanomaterial risk assessment methodology and tools development
- Integrate Key Environmental Performance Indicators into materials selection
- Additive processing
- Imprint patterning for advanced technology nodes
- Alternative low-ESH impact processes for planarization
- Alternative 3-D etch processes
- High efficiency rinses
- Real-time, on-line, speciating sensors for UPW recycle

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Addressing ESH During Technology Development

- **Early ESH risk information on R&D materials and processes is important to**
  - Prevent potential ESH showstoppers **(ensures materials with regulatory bans and policy bans are not being introduced)**
  - Minimize negative impacts and costs
  - Minimize future potential ESH liability
  - Avoid potential delays in process implementation due to ESH issues/risks
  - Allow for greater flexibility in considering technology options and making strategic business decisions

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Final Thoughts

From "Beyond The Green Corporation," January 29, 2007, *Business Week* cover story:

- **Assets of socially responsible mutual funds increased**
  - **$12 billion in 1995**
  - **$178 billion in 2005**
- **Sustainability factors *"…show that companies tend to be more strategic, nimble, and better equipped to compete in the complex, high-velocity global environment.*"**